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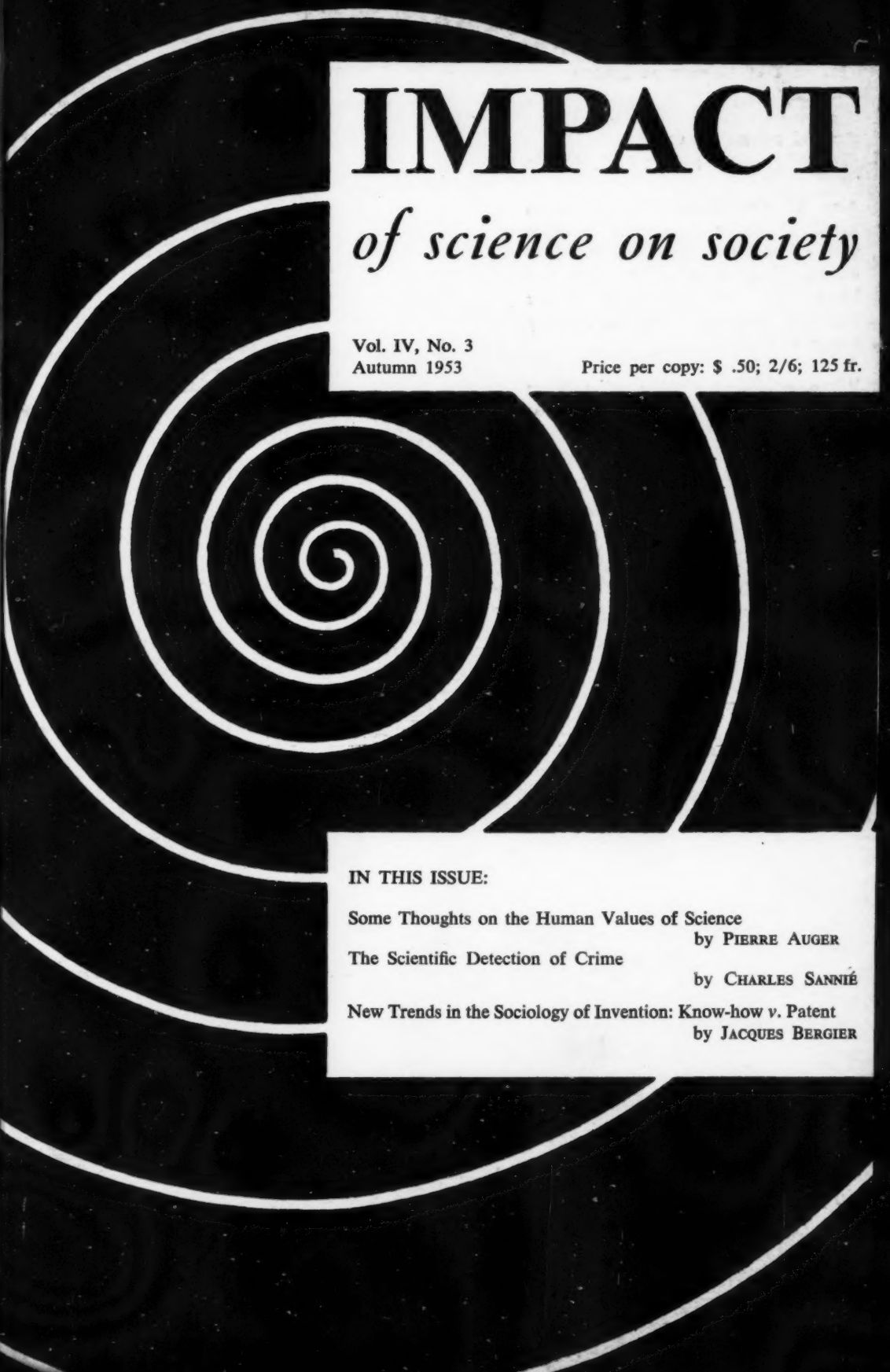

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SOME THOUGHTS ON THE HUMAN VALUES OF SCIENCE

by

PIERRE AUGER

This article is based on the inaugural lecture given by Professor Auger at the "Journées Médicales de Bruxelles 1953". Former Director of Higher Education in France, Professor of Physics at the Sorbonne and discoverer of the compound photo-electric effect (known as the Auger effect) and of the extensive atmospheric showers of cosmic rays (known as Auger showers), Professor Auger is at present Director of the Department of Natural Sciences at Unesco.

It is clear to everyone that the progress of science is one of the main features of our epoch; but opinions are deeply divided as to the human value of this progress and of scientific thought itself. Some condemn a scientism that is amoral, destructive and oblivious of human values, while others admire the achievements of a triumphant rationalism. These judgments are based on personal sentiments rather than on a reasoned analysis of the situation. In particular, the obvious effects and the spectacular results are placed in the forefront, whereas the fundamental human significance of scientific discoveries is left in the background.

I feel that, first of all, a clear distinction should be made between the peculiarly intellectual aspect and the practical aspect of scientific discoveries. Very often it is only under the latter aspect that a scientific advance becomes known to the public at large. There is no denying the importance of this practical aspect, but if our position is to remain valid, it is essential to recognize its secondary character, i.e. that of a consequence—and not an inevitable consequence, but one deliberately provoked by an act of the human will, an act distinct from the discovery itself. Moreover, if we try to situate these two aspects of science within the framework of the interactions between man and his environment, we must recognize that they are in the nature of creations or new departures, because both imply more than the mere intelligent application of the rules of tradition and instinct. Lastly, these creations are adaptive, i.e. they establish new relations between the internal structure of man and the structure of his environment.

Perhaps we can now more clearly define scientific discovery and technical invention. In the first, a new internal arrangement is established in relation to a natural phenomenon or a series of natural phenomena. This internal arrangement must harmonize with those that existed before it, modifying some of these if necessary; it brings understanding of the phenomenon or of

the laws observed. In technical invention, that is in the application of science, on the other hand, it is on the environment that a new arrangement is imposed, in accordance with an idea—an idea resulting from the internal rearrangements caused by the discoveries and they way they are interpreted. Thus invention is related to art, as is suggested by the common expression which links together arts and crafts.

The adaptation of our mental structures to nature, as our biological structure was adapted to it in the remote past, requires a series of operations involving the appearance of new characteristics and the selection from among these of the ones that promote progress. It also requires the subsequent maintenance of the improvements obtained. The new idea, its experimental testing and its inclusion in the fund of scientific knowledge correspond to these successive stages. As regards the adaptation of environment to our needs, this means that we shall have to invent and construct the corresponding mechanism and incorporate it in technical tradition and prevailing custom. The selection will be made at the level of an experimental test in one case, and on the basis of a utilitarian and economic trial in the other. The relation between these two aspects of progress results, in particular, from the fact that scientific discoveries provide ever fresh fields for inventions and that new machines make it possible to test by experiments new scientific ideas. The power of the mind and that of the body thus increase concurrently: the greater the understanding the greater the power. There remains the will, which determines the use that is made of the means of action thus acquired. I shall do no more in this context than define its proper place.

CLASSIFICATION OF THE SCIENCES

The problem of the human values of science, then, is twofold: the value of knowledge, the value of technical power, and their influence upon each other. For idealists, the first is the more important; for pragmatists, the second, since they regard the first as no more than a repercussion. From this point of view, it is instructive to examine the historical panorama of the progress of science and of its influence on technique and, for this purpose, to follow a classification of the sciences. Since it is desirable that this classification should be based on important criteria, we shall adopt Auguste Comte's classification which places mathematics first, then astronomy, physics, chemistry, the natural sciences, and lastly, psychology and sociology. The term "exact sciences" is frequently used to designate the group which ranges from mathematics to chemistry, whereas zoology, botany, geology and biology are all defined as natural sciences. In these circumstances, the other disciplines, i.e. psychology and sociology, are in great danger of being regarded as inexact—and supernatural—sciences.

If exactitude is not the exclusive attribute of certain sciences, if all sciences are equally natural, that being one of the fundamental qualities of the objects they study, on what criterion is our classification to be based? The best, undoubtedly, is that of complexity, provided the way in which it is to be applied is carefully defined. We have already seen that science means adaptation, effected by means of concepts, notions and general ideas usually designated by a word or a small group of words, the number of which cannot be increased indefinitely without exceeding our capacity to understand. Thus a certain harmony must be established between the order of complexity our thoughts can grapple with, and the order of complexity of the phenomena we regard as the subjects of science. It might almost be said that the order of the sciences chosen by Comte is the order of the increasing difficulties encountered in the establishment of this harmony, and this is true of a series of domains in the natural sciences.

This difficulty is not due solely or directly to the complexity of the perceptible effects, which is considerable in the case of any natural phenomenon; it is much more frequently encountered when these effects are being reduced to a much smaller number of complex parameters; a necessary reduction, let us repeat, if they are to be brought within the reach of our understanding. Let us consider, for example, direct observations of planets or of storms and their subsequent interpretation in terms of the positions of the planets in relation to the sun, or of the electric field of the clouds. It then becomes easier to understand the real importance of the classification: mathematics are practically in a class by themselves, since the parameter and the variables are deliberately chosen by the research worker, who sets the problems himself, whereas in the other sciences nature sets them for him. In mechanics—and generally in physics—the experimental data are not very numerous and it has been possible to reduce them to a very small number of complex physical magnitudes, such as masses and fields, charges and energies. In many cases, the main work of the theorist has consisted in discovering these essential parameters and elucidating their real significance. When we come to chemistry, it is clear that the variety offered by nature suddenly increases. There are some 100 elements whose combinations appear countless and whose properties are so capricious that for a long time it was considered impossible to reduce them to a logical order. The work of classification and the establishment of a utilizable terminology took a century to complete and the result is infinitely less simple than that obtained in physics. The same situation, even more pronounced, exists in biology whose vocabulary of new terms is in danger of exhausting the garden of Greek roots by too intensive cultivation. However, the mechanism of progress is the same: as the facts accumulate, a classification is made and fixed by a nomenclature; the relations and laws observed enable the theorist to discover the simplifying parameters, and the quantitative gradually invades the

domains in which the qualitative hitherto held sway. There remain the sciences whose subject is man himself—considered, not as a living being, but as a "thinking reed" and a social animal. In many cases, the magnitudes which would make scientific reasoning possible have not yet been discovered, because they are still obscured by the multiplicity of facts. The future will no doubt reduce this superficial *complication* to reveal the profound *complexity* of the phenomena themselves, and thus place them within the scope of human reasoning.

We shall revert to these different points later on, but, for the moment, let us be content to bring into our field of vision this garland of the sciences, this seven-coloured spectrum in which life occupies fifth place and man sixth. If we study it as an object in itself, and particularly if we examine its variations throughout the course of history, we shall pick up precious information on the way, even if this is limited to the remarkable discovery that the extraordinary changes brought about by 100 years of progress have in no way altered the validity of Comte's classification. If there has been a general shift towards the quantitative, this has not modified the order of increasing complexity we have just analysed. However, this rigidity of structure must not deceive us; it is that of a being instinct with life, whose individual physiology is the result of continual exchanges involving questions raised by the least advanced sciences and answers provided by the most exact sciences, a being capable of suddenly developing new organs. As this being is a continuous creation of the mind of man, let us first seek to determine the position of this man as a portion of the universe, in the various fields proper to these sciences.

SCIENCE AND SOCIETY

It is therefore important to perceive clearly, in the case of each science, the period and place in which it has a definite effect on the daily lives of men. We then note that each of the sciences, leaving the limbo of thought, "passes" before man during the course of its history and then moves further and further out of his reach towards the confines of the universe. It is during its passage through that part of the universe which is "on the human scale" that it brings us its most numerous practical contributions, which are not necessarily the most valuable ones. It is at this moment that it gives an impetus to techniques, whereas the aid given subsequently will be increasingly less perceptible and direct; the practical—visible—value of science then becomes obvious and renders access to it more attractive. Its spiritual value, on the other hand, is not subject to such considerations: in the effort to adapt our thought to nature, each progress in details is of value mainly for its repercussions on the whole.

Thus the stammerings of physics in its very early stages were not of much use, for instance, during the period when it held that stones thrown into the air described a circular trajectory; the archer, the architect, the well-sinker, the sailor, all based their techniques—sometimes precise and refined—on a long empirical tradition and not on the meagre knowledge of the scientists. The mechanical branches of physics reached a pitch of accuracy that secured their admission into the human sphere after Galileo: a case in point is the measurement of time by the pendulum. After remaining a long time in the human sphere, mechanics went beyond it at the end of the nineteenth century; since the advent of relativity and the quantum theory, the discoveries of mechanics are hardly more directly accessible than are those of astronomy. This latter science entered the human sphere many centuries earlier, with the use of the stars for navigation and with the establishment of the calendar. Since then it has disappeared into the nebulae and the millions of light-years.

The sciences of life, which follow the physical sciences in Auguste Comte's classification, were concerned, right up to the beginning of the last century, only with the search for first principles, and even then, often only with an adequate classification. It may be said that their real entry into the human field dates from the period of Mendel, Pasteur and Claude Bernard. It is only today that man has acquired real power over the living world: he determines and selects mutations, influences the development and the functioning of the organs, provokes parthenogenesis and geminate reproduction. Should we anticipate that, in a more or less distant future, the sciences of life will, in their turn, open up domains too remote from the phenomena that govern our daily existence, at the very time when the latter is rapidly moving towards regions of the universe formerly beyond its reach? It may be that research on the viruses, those already half-living molecules, will give the first indications of this tendency.

All this does not mean that the science of physics, for instance, has ceased to have important applications for the man in the street because its most brilliant work deals basically with ephemeral particles whose whole history, from creation to disintegration, covers only one-millionth of a second; nor does it mean that the discoveries of astrophysics can have no influence on modern techniques because they concern phenomena that occurred millions of years ago at immense distances from this planet. However, it is clear that the human significance of milliard-volt machines and of telescopes capable of detecting stars millions of light-years away is at present more of an intellectual than a practical nature, and that it is only by means of very indirect developments that the long and difficult research carried out in connexion with these "advanced" branches of science can be made "to pay", if I may use that business term. It is nevertheless during this last period that the results are sometimes most general in character and have

the most decisive purely scientific repercussions on the progress of the other disciplines. In biology, on the other hand, and particularly in biochemistry, we are perhaps now living in the period most productive of immediate results. Lastly, as regards sociology, since this science comes at the end of our classification, the various schools in evidence are still engaged in "conceptual" research, in tentative efforts to establish a methodology and in working out the appropriate basic doctrines. The very existence of such diversity among the groups of active research workers means that this science is already in the first stage of its development. It has not yet entered the stage when its findings can be applied to any wide extent: the importance of the present efforts lies in their "experimental" value, i.e. in the lessons to be drawn from their success or failure, and not in their practical results.

It is true, of course, that man himself is swept along by the great wave of progress and, as a result of technical advance, the domain of practical, useful action open to him extends to dimensions in time and space of which he was formerly quite unaware. In the days of the stage-coach the physicist was able to measure the velocity of light, but, since then, his discoveries have made it possible to travel around the world in three days. Unesco's Department of Natural Sciences is preparing a science exhibition which will probably be called "The Scale of the World". The object of this exhibition will be to show the extraordinary extension of the world known to science since the invention of the first telescopes and microscopes. The dimensions of this world may be estimated as 10 raised to the power of 40 or so, since the relation between the distance of remote spiral nebulae and the intranuclear distances is of this order. But the portion of this scale that is under the control of man's daily technical activity is limited to 10 raised to the power of about 15, which corresponds to the relation between the earth's meridian and the precision of mechanical work. Throughout the whole of ancient times this portion of the scale did not amount to as much as 10 raised to the power of about 10; it began to increase only as a result of the technical developments which made it possible to measure the dimensions of the earth and to grind optical glasses. This technical extension of the world known to man will no doubt shortly be continued by the sending of rockets to the moon and by the improvement of micromanipulators. At the same time as the sciences are constantly extending beyond the human field, the latter tends to catch up with them, thus enabling man to obtain an ever more complete control over nature.

PURE SCIENCE AND APPLIED SCIENCE

It is important to examine some of the consequences of the steadily growing distance between what may be called the spearhead of the exact sciences,

such as physics, and their field of application, i.e. the field which happens to govern phenomena on the human scale. A hundred years ago—let us repeat —the discoveries of physics and chemistry which constituted so-called pure science were from the outset very near to the human sphere and it was therefore possible to perceive almost immediately their practical applications. At present, the situation is completely different, since, as the phenomena with which the physicist and chemical research workers are concerned in the field of pure science are very remote from the field of practical application, it is no longer possible to grasp simply and directly the link between the discoveries they may make and the practical applications that will eventually be given to these. In my opinion, these facts are at the root of a situation that has often been denounced by the administrators of scientific research, namely, a kind of blindness which prevents industrialists—and those who have a general interest in improving the applications of science—from seeing the profit they would derive from such-and-such a development in the field of atomic physics or in the field of the chemistry of the free radicals. It is true that, in many cases, no one can tell them how the discovery of a new elementary particle or the study of the length of existence of a free radical might have an influence on productivity and the cost price. Nevertheless, as the history of science shows, this link exists and if we want it to be fully apparent, we have only to follow the sequence of studies and perfecting processes far enough to give it visible and concrete shape.

This mechanism seems fairly similar to that which governs the evolution of organized beings. It is now known that at the origin of every stage of evolution there are certain chemical changes in the hereditary patrimony of the species, i.e. chromosomal or genic mutations. This chemical transformation in itself seems to be completely unrelated to the evolution of the species: a double bond will be established, one amino-acid will replace another. It is only after the development of the living being in question, when the body of the adult is completely formed, that it will be possible to envisage the consequences, by noticing a change of colour, a transformation in the shape of the organs or some other new characteristic which, owing to its practical, utilitarian value, can favour natural selection. But if anyone should wish to obtain by artificial means mutations corresponding to the appearance of a particular characteristic that strikes him as useful, he would be quite helpless to do so, because he does not fully understand the mechanism of the development concerned and is therefore unable to determine what chemical transformation he should produce in the genes of the species envisaged.

Here, then, is a certain "gratuitousness" in the elementary act of creation which determines the constitution of a new hereditary patrimony; its consequences are unknown, and even the animal in which this genic mutation occurs does not experience them until its development is completed. As a

contemporary philosopher has pointed out, there are no problems in nature, only solutions. A mutation provides a solution to a problem that has not been raised directly. It is thus that the act of scientific creation in the advanced fields of research possesses, and must maintain, an element of gratuitousness. The scientist who achieves progress in the field of pure science generally does not know whether it will be possible to give it a practical application, nor the sometimes very complex train of events by which this can be done. He must not bother himself with this question which would merely hinder him in the exercise of his faculties of imagination and of rational deduction. The practical application must be made by a mechanism of the development type, which alone is capable of revealing the value of the "solution" thus given to a problem which had not been raised.

The comparison we have drawn with mutations might give the impression that scientists and research workers interested in pure science carry on their work at random, so that only the subsequent development of the practical applications of the results they obtain enables their discoveries to be evaluated. In fact, pure scientific research represents a perfectly co-ordinated activity of the human mind; but the principles governing this co-ordination disregard the possible value of the eventual application of the results obtained. What, then, is the nature of the force that sometimes impels the research worker to spend sleepless nights in his laboratory and to persevere for years in efforts that are often very meagrely rewarded? It is not, as we have already seen, the need to resolve concrete problems with a view to practical applications, but rather the love of exploration and a deep longing to discover the meaning of natural phenomena.

INTERACTION OF THE SCIENTIFIC DISCIPLINES

The scientific research worker might well take as his guiding principle the determination to see more clearly, to accumulate precise and well-conducted observations and experiments and to find a leading thread that will enable these to be organized on the basis of a small number of laws and principles within the compass of our reason. In terms of structure also, it might be said that the scientist seeks to discover the sequences of ideas that can be adapted as completely as possible both to the phenomena observed and to the fundamental structure of the human mind. The successive stages in the realization of such a programme have often been described: judicious classification of observations, elaboration of an adequate terminology, creation of the general concepts which make it possible to condense a vast number of particular facts, and lastly, formulation of the relations between these concepts in the form of a natural law opening up the possibility of foreseeing new facts.

The cycle of scientific thought and action, which passes continually through the stages of observation, conceptualization, theory and practice, thus seems to be a closed cycle capable of existing without contact with the facts of social life. It is true, indeed, that in certain branches of science, such as astronomy, that are remote from the human sphere, the interaction between daily life and scientific life is almost non-existent. It becomes stronger in proportion as the field studied comes closer to the domain of the facts of everyday life. However, this is only an occasional aspect of science as a whole, which must be considered in itself and for its own sake, the material advantages deriving from it being granted into the bargain, as it were.

We have digressed somewhat from our subject—the human value of science; but, perhaps it has helped us to perceive more clearly the underlying thread that links the various manifestations of scientific knowledge, and to isolate it from the innumerable applications of science by which it is frequently concealed from the casual observer. It represents the real values, for, from it, all future progress must proceed. Let us now study it in detail.

We have already shown that questions ascend and answers descend the classification scale. Chemistry asks physics for an explanation of the nature of chemical bonds, and physics questions mathematics about the form of the equations which account for the forces brought into play. The modern biologist welcomes the chemical research worker and the physicist to his laboratory with a degree of confidence that sometimes makes them ashamed of their helplessness—merely temporary—to supply the answers for which they are asked. That is all very useful and necessary; but great prudence must be shown in thus applying to complex sciences methods that have succeeded in the case of sciences where, in the nature of things, the data are less numerous. I shall merely mention two examples of this: chemical analysis in biology, and statistics in sociology.

When studying phenomena such as the chlorophyllian photosynthesis, during which an important chemical transformation takes place, the biologist thinks it natural to ask the chemical research worker—his neighbour on the floor above—to analyse the substances concerned and so provide him, partly at any rate, with the clue to the problem. It soon becomes obvious, however, that the chemical research worker's simple methods *in vitro* permit only rough and ready explorations among an extraordinary complex of very diverse substances—castings of a net, as it were, that provoke in the delicate sequences of successive reactions a perturbation whose exact importance cannot be estimated. Chemistry alone did not suffice, and it has been necessary to resort to the more refined methods made possible by the tracer-isotopes in order to follow more closely those exchanges of atoms from molecule to molecule, that result in the elaborate structures of sugars made of carbon drawn from the carbonic gas of the surrounding air.

As regards statistics, the situation is even more serious, because at the present time, they are the only mathematical methods that seem to be applicable to many sociological problems. This is no doubt only a passing phase, and more powerful methods are perhaps even now in process of being evolved. Consequently, it would be absurd to abandon such methods, but their use must not delude us concerning the value of the results obtained. They are, in fact, methods of simplification, applicable to phenomena too complex to be studied in detail, but they enable very numerous experimental data to be classified in a small number of categories, which are then dealt with as a whole. The science of thermodynamics is nothing more than a statistical theory of molecular movements and, as such, it has produced valuable results; but it did not in any way make it possible to fathom the mechanisms of interatomic actions. Only the direct study of the latter has thrown new light on the mechanism that governs them and has therefore made it necessary to effect radical changes in the statistical methods to be applied to them. When statistics are applied to the study of biological or human phenomena, the peculiar structures of the real individual actions that are the cause of results which cannot be considered except as a whole, are frequently unknown. In such circumstances, innumerable errors can be made in a rough and ready identification of the results of so many delicately distinct mechanisms. How often essential causes are overlooked, and innumerable errors of judgment are made regarding the fields of application! Without following the example of the tourist who inferred that all French women were red-haired because the first woman he saw at Calais had hair of that colour, it would be possible, nevertheless, to carry out conscientiously numerous investigations, accumulate facts and arrive at the conclusion that there was a high percentage of blondes—a completely false conclusion, because no account had been taken of a passing fashion for dyeing the hair. Statistics of marriage among members of an Indian tribe, such as the Omahas, where customs are very complicated, provide no useful information, and recourse must be had to detailed individual questioning and efforts must be made to free oneself from preconceived ideas and thus come to understand these customs.

Two things must be borne in mind: first, no theory is final; having a theory is like trying on a ready-made garment cut according to a pattern designed by our logic and which never quite fits the reality. Successive minor alterations sometimes improve it, but sometimes the pattern itself must be replaced by a better one. Secondly, we must never be discouraged by a problem that seems insoluble: the chemists, for instance, wondered how they could be expected to know what became of a particular atom of carbon, seeing that these are all the same; and yet the physicists soon provided them with atoms which, although chemically identical, were sufficiently different to be distinguishable from one another.

In spite of the difficulties and dangers of this heavy traffic up and down the scale of the scientific disciplines, it is essential for the progress of each one of them and particularly necessary for maintaining the unity of the grandiose edifice of science as a whole. If sociologists resort to mathematics before all the other sciences, that is because the real mechanisms they study are psychological and biological, and because it is by these means that those mechanisms will, in the end, be elucidated with some degree of precision. Nevertheless, by means of judicious simplifications—neglecting certain suitably chosen aspects—it is possible to obtain approximate results with which we must content ourselves for the moment. They are provisional structures, scaffoldings which will certainly have to be demolished later, but they are a necessary stage on the road to progress.

PARTIAL SYNTHESES

There is, then, a very real unity between the scientific disciplines which makes the men who take an active interest in any of them, whether as creators, teachers or amateurs, feel that they are members of one large brotherhood transcending all social or national differences. This unity scarcely seems compatible with divisions or barriers between the various branches of science and, in fact, it is frequently for fairly prosaic needs of administration and nomenclature that such distinctions are made. Local syntheses, liaisons between related sciences, have been established during the evolution of these sciences and have sometimes given rise to genuinely new disciplines whose origin is now recognizable only through their compound names. The close relationship between the numbers and movements of the stars soon became apparent, and astronomy thus became the most mathematical of the natural sciences. Astrophysics, physical chemistry, biochemistry, human biology and psychosociology have filled up all the existing gaps, and we are confronted with one great, continuous science. It is like some wild region in which the first explorers recognize and name, here a chain of mountains, there a river, and leave it to succeeding generations to fill up the gaps and discover the various links which will make it possible to understand how the river took source in the mountains. Events are moving so rapidly nowadays that we sometimes have the impression that we are watching the last pieces being fitted into a jig-saw puzzle, when the picture is already fairly clear, and we can see almost at a glance the shape the missing pieces should have.

We must not forget, of course, that the picture, when completed, will still be only a reflection of reality or, at best, one of its forms, and that soon observations and measures will have accumulated—perhaps they already have—that will oblige us to set to work again according to a new formula.

Science lives by a perpetual re-examination of all problems and is diametrically opposed to every form of dogmatism that would paralyse it. And exalting indeed are the moments when the search for the missing links is almost completely successful and there is the half-certainty that a synthetic view is about to appear. I cannot resist the pleasure of giving a few examples of these partial syntheses uniting branches of science formerly separated by seemingly unbridgeable gaps. One of them results from the nuclear theory of the stars. I remember having attended in the twenties a magnificent lecture given by Langevin, entitled "Atomes et Etoiles". "Noyaux et Etoiles" would be a very good title for an introduction to modern astrophysics, in which reactions obtained *in vitro* at the cyclotron and synchrotron laboratories are applied *in vivo* at the very centre of the suns and supersuns of the universe. Is it astronomy? Is it physics? It is science. On a smaller scale, those of us who have carried out research in the field of radiations, and who remember having studied for our degree a theory then considered very daring, called the electromagnetic theory of light, have not forgotten the satisfaction we all felt when the junction between Hertzian waves and infrared rays demonstrated the fundamental unity of all the modes of transport of energy without material support.

Other examples, perhaps less enlightening, but more closely related to our nature as living beings, are to be found in the borderland—in which there are still gaps in our knowledge—between living matter and chemical matter. The general public was made aware, some time ago, that the rather crystalline nature of the filterable viruses had been discovered. Competent scientific circles were in little doubt that a close relationship must exist between these three most elementary aspects of life; the viruses, the bacteriophages, the chromosomal genes. The extreme smallness of the elements in question, their relative independence as regards the general metabolism of matter living on a large scale, their fundamental characteristic of auto-reproduction, all pointed in that direction. In fact, however, the situation is quite different. The viruses have been characterized as large chemical molecules, crystallizable, permanent, and no doubt capable of being completely described by an elaborate formula of the classic type (although extremely complicated and extensive!). The virus of a rat which had been left forgotten for 30 years in preparations of dried blood has just been tried out again: it had lost none of its properties. On the other hand, the phages, studied with the help of the electronic microscope and X-rays, have revealed that they are composed of small hexagonal crystals with a pyramidal point and that their structure is a double spiral made up of molecular chains of nucleic acid. Why do these structures reproduce themselves in an appropriate environment? Perhaps the double nature of their basic structure will soon make us familiar with this mechanism. In any case, we have here a significant analogy with the phenomena of the duplication of chromosomes. All this, of course, is not yet

the secret of life, but we are drawing nearer to it. In another region of biology, the more familiar one of the physiology of the senses, the interpretation of vision has taken a decisive step forward as a result of a biologico-physico-chemical synthesis. The nature of the substance which, under the influence of luminous photons, suffers a rupture in the chemical bond that determines the appearance of an electromotive force while itself playing the role of an excitant of the nerve ends, has just been elucidated.

We can proceed even further in the series of the sciences and, for the first time in history, we can witness the birth of veritable syntheses embracing the sciences of man and relating them to the exact sciences, since the latter have invaded the natural sciences. The science of cybernetics has become a matter of interest to everyone; it has given rise to absurd hopes and fears, which are kept alive in a deplorable fashion by sensational press articles. The nonsense already published with regard to electronic machines—which were said to be capable of taking over the control of human affairs—has even been surpassed by the announcement that a robot poet has now been constructed! In fact, the science of cybernetics is simply a brilliant scientific synthesis of the physiology of the nervous system, psychology, physics and mathematics. It enables us to understand the physical meaning of transmitting a message, and thus heralds great progress in the science of communications and automatic mechanisms. In certain cases, this can go a long way: the analysis of speech, for instance, reveals the presence in us of a talking machine that presents us at every moment with different words, all *a priori* utilizable, among which we make a choice in order to render our intention intelligible. It is obvious that, in very many cases, man can, and should, be replaced by new machines; but the fact is that man has already been replaced by steam-engines, machine-tools and automatic pilots, which liberate him from tasks that do not require the exercise of his highest faculties—those that distinguish him from all other living beings—and so enable him to use his time and energy to greater profit. The more the mind of man is freed from the necessity of having to deal with trivialities, the more time it will have to devote itself to the noblest of all activities, and one denied to machines: creation.

GREAT SYNTHESES

Satisfactions of the kind we have been considering are within the reach of the average research worker who suddenly perceives the connexion between a series of phenomena and finds their common parameter; but only geniuses, like Newton, Darwin and Einstein, can effect great syntheses. If we consider only the most general of these, the ones that are the product not of one man but of an entire epoch, and which stud the path of scientific progress since

ancient times, we might perhaps acknowledge four or five as belonging to this category of great syntheses. Each of them centres around the science that was most developed at the time, but includes aspects of nature taken from all the other sciences.

In chronological order, the first might be attached to the name of Pythagoras, for in the simplicity of numbers, and of geometry, it seeks an explanation of everything which surrounds us. The famous sayings, "all things are numbers" and "God is a geometrician", sum up this tendency, which lasted until a more subtle and complex order was attributed to the movements of the planets and was then extended to the movements of terrestrial bodies. The arithmetical and geometrical structure of the universe seemed to impose on the cosmos, as the price of its unity, an icy immobility. The trajectories of bodies were held to be circular because of the global simplicity of this type of movement, and not because of any continuous law. Everything was contained in everything, and the link between the different parts of the cosmos was fixed in advance and for ever.

The second synthesis, that of universal mechanics, must certainly be named after Newton. Forces and velocities in continual movement replace the fixed numbers of the previous synthesis. All objects are linked together by these forces, but it is possible, by computation, to isolate the various systems in order to determine all their past and future aspects, starting with our knowledge of the present. Absolute determinism reigns in this world of differential equations. Light is a bombardment of subtle projectiles, and atoms are perfectly elastic spheres. Whereas the synthesis of the ancients was based on mathematics, the world of Newton was based on mechanics and astronomy.

The nineteenth-century synthesis, based on the concept of energy, brings physics and chemistry into the centre of the picture. With thermodynamics and thermochemistry, a statistical conception of matter comes into existence. The systems studied pass from one state to another with exchanges—it is well known that the real vehicles of the latter are the elementary particles, atoms and molecules—but their total effect only is considered. Chemistry certainly offers a great variety of species of these particles, whose fundamental relations cannot be discovered by the methods of analysis employed. To make the best of this situation, the research workers regard them as immutable data established once for all. It is interesting to note that, at the very moment when this idea of the single creation of a variety of immutable species was accepted with regard to chemistry, it was finally rejected—thanks to Darwin —with regard to living species. However, as we now know, this did not involve any contradiction, since living species are homologous to chemical combinations and not to atoms. When it was at the height of its fame, the Newtonian synthesis, prolonged by the synthesis based on the notion of energy, gave rise to great hopes: it was thought possible, at last, to include

all natural phenomena in a single system. The discovery of its inadequacy produced in many a sense of total failure; but this simply showed that the real significance of such efforts had not been clearly understood.

This science of the continuous and the statistical at last ran up against phenomena of an individual and discontinuous type in the fields of chemistry and biology, and finally encountered an insuperable obstacle in the field of physics with the appearance of the quantum of action. It is these circumstances that have given rise to the most recent of the great syntheses, the one that marks our own epoch and which can be characterized by the rebirth of the concept of the individual that had almost disappeared from the Newtonian universe. The individual, not merely ignored but deliberately obliterated by the statistical form of the laws, once again assumes an essential role, whether in the form of the atom, the molecule, the chromosome or the living being. With the reappearance of this element of discontinuity which approximates to certain Pythagorean propositions, the problems of determinism and finalism also reappear, though in a new form.

In a recent work,[1] I have tried to give a general outline of science viewed from this standpoint. In spite of considerable gaps, it is possible to observe a large generalization of quantic properties of the atom through a series of increasingly complex individualities: molecules, genes, viruses and phages, living cells, and so on, right up to the human brain.

CONCLUSION

It is possible to be alarmed at these advances of science and to fear these bold generalizations and technical developments, but it is impossible not to admire them and be proud of them. We cannot stint our admiration for those who suddenly open up new fields of vision or dedicate their lives to humdrum research so that their successors may have that joy. If we ask why scientists should thus devote all their intellectual—and sometimes physical—resources to the cause of scientific progress, we shall find, in the last resort, that it is because of the research worker's profound conviction that the forces of the living universe are concentrated in him—forces that have lain dormant for hundreds of thousands of years in the seed of the successive species, awakening only now and again in order to take a creative but blind leap into the unknown. It is now upon the mind of man that devolves this creative function, for so long the exclusive attribute of the molecules of nucleotides of the chromosomes. The adaptation of life to the physical universe—in which it multiplies—continues at an extravagantly accelerated rhythm owing

1. Pierre Auger, *L'Homme Microscopique*, *"Bibliothèque de Philosophie Scientifique"*, Flammarion, Paris, 1952.

to this replacement of the Darwinian mechanism (chemistry and natural selection) by the rational mechanism (invention and experiment). At the same time, this new mechanism has put an end to the egoism of lineage, that direct lineage which formerly was always the sole beneficiary of the improvements resulting from individual mutation; it is now the entire human species that receives the benefit of each of the discoveries of science; these are also individual by nature, but immediately communicable to all. Although, alas, it is still true in many circumstances that man is a wolf to man, in the exercise of his creative functions, at least, he always acts on behalf of the species.

THE SCIENTIFIC DETECTION OF CRIME

by

CHARLES SANNIÉ

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Every human society, even the least advanced, has been obliged, in face of certain antisocial acts imperilling its very existence, to draw a distinction between lawful and unlawful conduct. The concept of crime and misdemeanour is thus inseparable from the concept of society itself, and the struggle against crime is a social necessity of overwhelming importance.

Although it may appear self-evident, this idea has not always been fully grasped, because it was overshadowed, for a long time, by religious considerations. All religious doctrines lay down moral laws, defining right and wrong and holding out the prospect of reward for virtue and punishment for evil. They correspond to the rules of social defence which are essential to community life. Parallel to religious rules, legislators have drawn up codes of behaviour, listing legitimate acts on the one hand, and antisocial acts on the other, the latter being forbidden and subject to penalties varying according to the gravity of the offence.

In order to enforce the law, the first step is to discover the crime and then to trace the guilty party. This is the principal task of the judge or of the officer of the law responsible for establishing that an offence has been committed, for identifying the offender, collecting proof of his guilt and discovering his motive. The file transmitted to the judge must contain the complete story of the crime and enable the judge to estimate the criminal's responsibility and inflict upon him the penalty provided for by the law.

Thus it is the examining magistrate—or his assistant, the policeman—who is the first to learn the facts of a crime. By making a systematic study of the conditions, circumstances and environment in which the crime was committed, he manages to reconstruct the facts as they occurred and discover the perpetrator. What methods does he employ, how have such methods been developed, and why do the police resort more and more frequently to modern scientific techniques?

METHODS OF JUDICIAL ENQUIRY

Methods of judicial enquiry differ considerably, both in theory and practice, according to the legislation in force in each country; they fall, however, into two main categories, i.e. methods employed in Anglo-Saxon countries, and those employed in Latin and Germanic countries.

Accusatory procedure, which is the older, consists in bringing two adversaries face to face. Defendant and plaintiff debate the case, *orally and publicly,* in front of a judge or jury acting as an impartial arbitrator. No proceedings can take place without an accuser, and, when dealing with offences under common law, the policeman is the Public Prosecutor; it is his duty to prove, resorting to all the means in his power, that a breach of the law has been committed.

Inquisitorial procedure, consisting of *written and secret* evidence, is entirely different. In this case, it is the magistrate himself who seeks for evidence and collects it in a file, which he then hands to the judge or jury responsible, in the last resort, for deciding whether the accused is guilty and what penalty should be imposed.

Accusatory procedure, most clearly described as a "judicial encounter", has, in almost every case, been the earliest to be adopted, and is still the main feature of the judicial proceedings of African tribes, where trial by ordeal, or "the judgment of God", still sometimes plays a vitally important part. In England, it remains the foundation of criminal procedure and explains the very nature of proceedings in English courts. Although it has reached a stage of perfection in that country, the Latin peoples do not find it sufficiently logical and, ever since the Roman Empire, they have preferred an inquisitorial system. After a short period of revival in France during the Middle Ages, accusatory procedure once again vanished and, since that time, the inquisitorial method has been employed, except in England, by all European countries.

Whatever the procedure adopted, however, the detection of crime is always based on the same principles. In order to punish an offender, after proving that there has been a breach of the law, evidence must be adduced, proving that a certain person is in fact the guilty party. All criminal procedure, whatever its nature, is thus based on a *probative system;* in administering justice, the truth is not discovered—it is proved.

For the collection of the necessary proof, the police officer relies on two methods complementary to each other, differing widely in nature and technique and whose relative importance has varied through the centuries; the first consists of obtaining evidence from human witnesses, and the second of obtaining evidence by studying the facts.

Human testimony is obtained by examining the accused or witnesses; this is essential to any investigation, and explains why it is necessary to be a

good psychologist in order to be a successful investigator. The report of the examination remains the cornerstone of the preliminary investigation; many writers have explained how it should be drawn up, and have worked out a set of rules, but they have also drawn attention to its shortcomings.

Evidence obtained from human witnesses has already been sufficiently criticized.[1] To seek for the truth in statements made by an accused person who cannot speak the truth without condemning himself is hazardous, to say the least. The same is true of the evidence given by his relatives, his children, or his servants; it is so true that it is forbidden by law to put them on oath before examining them. Although "the right to lie" may appear open to criticism, it is nevertheless a fact which has to be accepted, and the probative value of such statements is always very slight, or even non-existent.

The same is true, though to a lesser extent, of most evidence given by human witnesses. Even a witness involved only by chance in a crime, and having nothing to gain by lying, may make mistakes, and often does. There are classical examples of the unreliability of memory, even in the case of recent events, showing how several people, all acting in good faith, may remember the same series of events differently. A witness' physical or mental condition may influence him without his being conscious of it, so that he sometimes distorts the facts beyond recognition. In addition, it is not unusual for an investigator to suggest untruthful replies by the manner in which he puts his questions. That is the danger of examining witnesses by means of leading questions, and such interrogations have been responsible for a great many false admissions.

The proof which an investigator is most anxious to obtain is the "final proof", that is to say, confession. With the inquisitorial system, if suspects refused to confess, the police used to resort to torture, although, as La Bruyère said: "It is a method calculated to lead an innocent man, of weak resistance, to the gallows and to enable a guilty man, with a strong constitution, to escape justice."

When public indignation led to the abolition of torture at the end of the eighteenth century, the only other known probative method was interrogation or examination.

In forming his own private judgment, the examining magistrate relies on such examination of the accused; he will obviously feel far more satisfied in his own mind when he has managed to obtain an actual confession; he can then conclude his investigation with a clear conscience.

Whatever the methods of criminal procedure or judicial inquiry employed, there is no disguising the fact that human evidence, in spite of its weaknesses,

1. Any reader interested in this subject would do well to refer to *L'Appréciation des Preuves en Justice*, Paris, 1947, by F. Gorphe, which is a classic, and to the report presented by Dr. M. Cénac, to the Fifty-ninth Congress of Mental Specialists in 1951.

still is and will remain, at least for many years to come, one of the most important factors in any investigation. Later on, we shall see how efforts have recently been made to remove the arbitrary character of human evidence and reduce the possibilities of error, by introducing scientific methods. Human evidence was so unreliable that it had to be supported by surer proof, and especially by the evidence of facts. In order to satisfy himself of the guilt of the accused, the investigator was obliged to seek conclusive evidence independent of human statements.

If he had not done so, the magistrate would have had no other choice than to replace the evidence extorted by torture—unreliable though it was—by his own subjective intuition and personal impressions, thus reverting to a primitive form of justice, more or less based on guesswork, which was precisely what has to be avoided. For the future of the probative system, it was thus essential to introduce scientific methods into criminal investigation.

INTRODUCTION OF SCIENTIFIC METHODS

The first science to be used in criminal investigation was forensic medicine. Very often, an examining magistrate learns far more from the medico-legal examination, or autopsy, than from all the evidence supplied by witnesses, because no witness can know exactly what only such an examination can reveal. It confirms or disproves the fact that rape has been committed, and reveals the existence of internal injuries, which are sometimes fatal but have been caused by blows leaving no external mark; or, on the contrary, it shows that a death, which at first appeared extremely suspicious, was in fact due to natural causes. A medical expert often establishes the causes of death beyond all doubt, describes the weapon used, the way in which it was employed, and the immediate or delayed effects of a wound. Nowadays, a criminal investigation failing to start with a post-mortem examination would be inconceivable, and the law has quite rightly made an autopsy compulsory whenever permission to bury the body is withheld.

It is even more necessary to employ scientific methods in cases of poisoning, for it is obvious that a "chemical crime" is directly connected with chemical methods. Thus toxicology, a science dealing with accidental or intentional poisonings, came into being in the middle of the nineteenth century and developed side by side with the chemical sciences. As a poisoning cannot be discovered unless the chemical substance employed by the criminal is identified, the only way of bringing the crime to light is to make a chemical analysis of the substance concerned. One of the earliest examples of the importance of chemical methods in criminal proceedings was the famous controversy which brought Orfila into conflict with his colleagues in the Lafarge case (1840); this controversy would never have arisen had the

chemical methods used during the proceedings not been so ineffectual. Even in our own time, is it not true that disputes still arise between toxicologists, and are nearly always due to the imperfection of the scientific techniques employed? This goes to show how greatly the improvement of a scientific method in this field can further the cause of justice.

Up to 1880, the chemical crime, i.e. poisoning, was the only form of crime to which truly scientific methods were applied. Apart from the evidence supplied by the medical expert, the investigator relied solely on evidence given by human witnesses. Bertillon was the first to introduce factual evidence systematically into the detection of crime. At that time, and almost simultaneously in all European and American countries, it was at last realized that every criminal leaves behind him some tangible evidence of his crime, which, if correctly interpreted, may, independently of all human testimony, supply proof or circumstantial evidence of immense value. Such was the origin of scientific criminal investigation, i.e. forensic science, which has made steady progress during the past 50 years; there is a growing tendency to substitute it for verbal evidence or, at least, to have it reinforce the latter as effectively as possible.

SCIENTIFIC DETECTION OF FALSEHOODS

It was inevitable that the progress of scientific methods in the field of factual evidence should have repercussions on evidence given by human witnesses. As early as 1892, Ferri had advocated, in his *Criminal Sociology,* the use of hypnosis to "try out the reins and the heart" of a criminal and reveal his innermost thoughts. Lombroso used a sphygmograph to register a suspect's emotional reactions. Research on the possibility of detecting lies by testing a suspect's pulse, blood pressure, respiration, psychogalvanic reflex or electric reactions of the skin, etc., was carried out by Muensterberg in 1904, Marston in 1915, Larson and Vollmer in 1921 and Father Summers in 1932.

In the application of scientific methods to the interrogation of human witnesses, two very different lines have been followed. Under the first system, the aim is to suppress the consciousness of the individual being questioned, so that his subconscious may be freely explored. Although all methods based on hypnosis have failed, those involving the use of artificial sleep have made great progress in the last few years; achievements in this field are, moreover, closely connected with those in the field of chemical synthesis. In the past 30 years, a constantly increasing number of hypnotics, producing an ever wider range of physiological reactions, have become available to doctors. The most recent barbiturics make it possible, before sending the subject off into a deep sleep, to keep him in a somnolent state, in which his consciousness is suppressed but his subconscious continues to

function. While he is in this state, an individual can answer the questions put to him, but he can no longer control his replies; it is thus possible to obtain information from him which he would never have given, had he been fully conscious.

This method of questioning the subconscious is commonly used by psychiatrists in order to diagnose mental diseases accurately; it is called narco-diagnosis. It has also come to be employed, as "narco-analysis", in forensic psychiatry, particularly for disclosing simulation. During such medical examinations, some subjects have confessed to crimes which they had committed, and this raises the question whether their confessions should be used in the course of the legal proceedings. This suggestion, however, has met with violent opposition, on the ground that the procedure involves a real "forcible entry" into the human personality; certain experiments, even in the medico-legal field, have aroused very strong feelings. All those who consider that the innermost recesses of the human mind are sacred and should not be tampered with are categorically opposed to this method.

This is not the place to raise the question whether the interests of society should not take precedence over those of the individual and whether the accused's right to lie should be respected. However, there is no doubt that narco-interrogation raises moral and social problems of prime importance and it would appear premature, at the present stage, to introduce it into criminal investigation.

Working on parallel lines, but without using hypnotic methods, other research workers have tried to obtain from suspects, who were fully conscious, replies of a kind enabling them to discover whether the subjects were lying or not. They apply the various physiological tests already mentioned, using a single apparatus, namely the polygraph or lie-detector. The principle is to register simultaneously, on the same recording cylinder, the subject's physiological reactions while he is being asked very precise questions relating to the case at issue. The physiological tests applied are rhythm of breathing and heart beats, blood pressure and electric resistance of the skin. The examination consists of a certain number of questions (not exceeding 15), some having no direct connexion with the crime, and the others, on the contrary, being directly related to it. The subject must answer "Yes" or "No" and, by comparing the physiological reactions to "pertinent" and "neutral" questions, it is possible to detect untruthful replies to the former.

It is quite obvious that, in this case, there is no "forcible entry" into the private recesses of the human personality. The subject is free to accept or refuse the tests; he is master of his own replies, and only his physiological reactions can betray him. If the test is to be of any value, there must be no coercion, and it has in fact never been suggested that there should be. Further, it should be noted that this method does not result in a definite confession, but leads to it indirectly by proving that the individual questioned

has lied; the guilty party's ultimate confession is thus only a *consequence* of the test.

This form of interrogation with the help of a polygraph has been studied in particular by Professor F. E. Inbau, of North Western University. In the United States of America today, some 60 police services and various private institutions, as well as the army, use Keeler's polygraph to detect falsehoods and test their employees. According to Keeler and Inbau, successful results have been achieved in over 80 per cent of cases; it would thus appear to be an extremely effective test.

The use of this method has, however, given rise to a certain amount of criticism. Some particularly phlegmatic individuals do not show the normal reflexes when telling a lie. Others, on the other hand, are over-emotional and the reflexes of these may be misinterpreted. However, no method of interrogation is infallible and, so far, no apparatus which will guarantee 100 per cent success can be conceived. It is nevertheless striking that even a thorough knowledge of the instrument does not enable an experienced subject to prevent it from betraying him. For example, a student who had had a great deal of experience of this apparatus was one day suspected of theft. Despite all the care which he took over lying and controlling his reactions, the polygraph detected his lies; it was subsequently proved by the investigation that he had, in fact, stolen.

Should the polygraph therefore now be employed generally in criminal investigation? There is no doubt that this instrument is particularly valuable from the standpoint of research. However, its employment calls for highly competent interrogators, and it does not seem that it can be put into general use before the latter have acquired the necessary experience.

In any case, the polygraph marks the introduction of purely scientific methods into the examination process—methods which will certainly end, one day, by transforming and simplifying it, while increasing its probative value. The past 20 years show, in this respect, an evolution parallel to that which, as we shall now see, has taken place in the realm of facts.

THE BEGINNINGS OF FORENSIC SCIENCE—ANTHROPOMETRY

Conscience forbids our allowing an individual to be punished for an offence he has not committed. The first duty of the law is therefore to discover and identify the guilty party. The identification of the criminal is of still greater importance when there is any question of applying the laws regarding persistent offenders, which prescribe heavier penalties for other than first offenders.

There are thus two quite different aspects of judicial identification. Firstly, it is necessary to discover the person guilty of an offence, or, in other words,

to prove that the person in question, and he alone, has committed it. Secondly, when a delinquent is thus convicted of a crime, it is necessary to investigate whether he has previously committed other offences, in which event a heavier penalty would be entailed.

Bertillon was the first person to solve this problem and, from this point of view, must be considered a pioneer. Before 1885, there were no exact rules for the recognition of old offenders. The most usual method was to introduce prisoners in the pay of the police into the cells of the individuals suspected of having committed previous offences, with the object of getting the suspects to talk and obtaining information from them, directly or indirectly, about their past life. Or else, if this method failed, another course open to the police was to parade the prisoners arrested the previous day, to see if they recognized any of them. If the latter denied accusations, it was impossible to prove that they were lying. In practice, all these methods failed in over 80 per cent of cases.

People had, of course, already thought of using photography to identify criminals; and as early as 1854 an examining magistrate in Lausanne succeeded in having a dangerous criminal arrested in the Grand Duchy of Baden by circulating a daguerreotype of the "wanted" man through all the Swiss cantons and the adjacent countries; but such cases were the exception rather than the rule. The introduction of gelatino-bromide plates and papers, which made it easier to obtain negatives and to print copies, enabled certain police departments to build up photograph albums of portraits of criminals known to the police, in order to facilitate their subsequent recognition. Experience showed that the desired aim was seldom achieved, for the very simple reason that, though it was easy enough to build up files of photographs of all persons arrested or convicted of an offence, it was impracticable to trace such persons in the files.

It was, in fact, impossible to devise a systematic method of filing these photographs so that the individual sought could be found by a gradual process of elimination. The more photographs were added, the more difficult the problem became; and despite all its apparent advantages, the system had to be dropped. Bertillon himself later tried to develop a suitable filing system, but he, too, failed.

When however, in France, the Law of 27 May 1885 introduced transportation as an additional penalty for certain persistent offenders, it became urgently necessary to find a more satisfactory solution. Since 1878, Bertillon, a clerk at the Préfecture de Police, had been responsible for filing the cards of persons already convicted. He had been struck by the poor and unsatisfactory means employed for that purpose, and set out to find a solution for the problem.

Very often advances in a science are achieved by people who are not primarily concerned with that science. Pasteur was a chemist and minera-

logist, but it was his discoveries in the field of medicine which immortalized him. Bertillon was not a policeman but, by training, background and heredity, an anthropologist. His father, grandfather and brother did anthropological work. It was the time when Broca's school was at its prime. Throughout his youth, Bertillon had associated with the foremost anthropologists in France and Europe; with these he had discussed the value of anthropological measurements, and he was familiar with them all. It is therefore not surprising that he should have thought of applying these methods—accurate methods based on exact measurements—to the solution of a problem which appeared to have no connexion with them.

To identify anyone is to establish a relationship between a given individual and certain morphological characteristics observed in that individual. But these morphological characteristics must satisfy certain imperative conditions, having regard to the aim in view. They must be absolutely stable throughout the life of the individual; they must, at the same time, be as specific as possible, i.e. the group of characteristics found in any given individual must be found only in that individual and in no other. Lastly, they must be easy to record, with the use of simple equipment and elementary methods.

Bertillon approached the question as an anthropologist and, in developing his method, selected the forms of measurement with which he was familiar. The only anthropometric measurements that can easily be taken from a living being with sufficient accuracy are the dimensions of the bones. He therefore chose bone measurements, although they did not fully satisfy the two conditions mentioned above. They are not absolutely stable throughout life, and they change until the process of growth is completed. Secondly, they are not strictly specific, even when considered in combination. Our department has come across certain twins whose measurements were, as nearly as could be measured, exactly the same.

Despite these drawbacks, Bertillon succeeded in assembling on a single card a collection of bone measurements distinguishing any given individual. At the same time, he worked out a method of filing which enabled him unerringly to trace the individual for whom he was looking from among the hundreds of thousands of cards accumulated. He reduced the inherent disadvantages of bone measurements by adding to the purely anthropometric details a note of any distinguishing marks, such as warts, scars, tattooing, etc., which are highly individual when their exact situation, size and direction are clearly indicated.

Bertillon's method was strikingly successful. For the first time, thanks to accurate scientific methods, it was possible to refute the lies of an old offender who denied his previous misdeeds and, irrespective of what he said, to establish his true identity. Despite the difficulties involved, and the complexity of the method, it spread all over the globe in a few years, and by

1895 most police forces throughout the world were using the Bertillon system.

FINGERPRINTS

But a formidable competitor was soon to oust Bertillon's system. The work of Galton in England, following that of Sir William Herschell, Faulds and Vucetich, had established that fingerprints could very well take the place of bone measurements. The system of ridges in the skin, forming regular lines all over the inside of the fingers, the palms of the hands and the balls of the feet, proved to be infinitely better, for the purpose in view, than any other morphological feature. Experience over a period of more than 70 years has shown that the system is absolutely stable, not only throughout life but before birth, from the fourth month of the mother's pregnancy, and after death, until the total destruction of the skin. All police forces throughout the world have identified drowned bodies found several days or sometimes weeks after death, by removing the saturated epidermis and taking prints from the exposed ridges in the corium. The probative value of fingerprints as evidence in the identification of human beings is universally recognized.

A few years ago, however, some anxiety arose. L. Ribeiro had observed that in leprosy, in which trophic disturbances usually affect the extremities, progressive changes took place in the ridge patterns, sometimes almost totally obliterating them. The same series of observations established however that, if the disease was treated and an improvement set in as a consequence, if the trophic disorders were brought to an end, the ridge patterns returned in exactly the same form as they were before the illness.

It still had to be proved that in no case were there two identical fingerprints. Admittedly, when we examine fingerprints, we see that there are only a few general patterns—four or five at the most. When, however, we go into the details of the ridge system, we very soon find that there are always differences in the morphology of the patterns, by which one can be infallibly distinguished from another.

In point of fact, despite the countless comparisons of fingerprints which have been made by experts throughout the world for more than 50 years past, no two identical prints have ever been discovered. Experience, in this case, has confirmed theoretical calculation.

When a fingerprint is examined in detail, it will be seen that it is made up of a series of ridges and depressions, running parallel to one another and arranged more or less regularly around a central point roughly in the centre of the fleshy pad. These ridges form either more or less flattened arches, or loops opening to the right or left, or, again, more or less complicated whorls. At the base of the finger, there is a system of ridges roughly

parallel to the line at the joint. The meeting place of this system and the other is formed by triangular points in the shape of a Greek "delta", by which name they are, incidentally, known.

These papillary ridges are not absolutely regular, however; in some cases, they are broken and end abruptly; in others, they split in two; in yet others, they form islands between two longer ridges. Each of these irregularities is useful for identification purposes. Taking their presence and position in the print as a basis, Balthazard, by a simple calculation of probabilities, has shown that approximately 1,074 million prints would have to be examined to find two prints showing 15 points of coincidence in the ending of their lines or their bifurcations.

The first joint of one finger alone contains more than 100 of these identification points. One finger can therefore definitely reveal the identity of an individual, and indeed a portion of a print may be enough. The whole system of fingerprints is based on this principle.

Lastly, a fingerprint is extremely easy to take. All that is needed is a plate covered with ink on which the finger can be rolled. Fingerprints are thus the ideal morphological characteristic for identifying individuals; throughout the world, they have taken the place of Bertillon's bone measurements, which are now of no more than historical interest.

It is not enough, however, to have found the ideal morphological characteristic; it must also be suitable for use in a card index system and for the tracing of cards. Several methods are used; in the English-speaking countries, they are derived from the Galton-Henry system and, in the Latin countries from the Vucetich system. All these systems use the basic ridge patterns of the fingertips and differ in their methods of secondary classifications. Prints are traced by going through the files themselves.

It might be thought that no further progress could be made in such a field; and indeed the largest filing systems, sometimes including several tens of millions of cards, are entirely satisfactory. None the less, a mathematical study of the problem of tracing an object with rather indeterminate characteristics among a group of similar objects has recently made possible a considerable improvement in the tracing technique, thanks to the use of a supplementary card index made up of perforated cards. Efficiency is, as a result, several thousand times greater than before. A search which used to take several hours can be completed in a few minutes. This system has been developed entirely by mathematical reasoning based on the theory of sets, though a large number of statistical calculations with computing machines were also necessary. It is a very clear, and recent, example of the advantages of using a scientific method, in this case associated with a complicated branch of mathematics, in what seemed to be a totally unrelated field.

Before leaving this matter, we must point out that it is impossible for the police to trace an individual in a big 10-finger filing system, when they have

only more or less perfect prints of one, or even two or three of his fingers. At the scene of a crime or a burglary, fingerprints are very often found on objects that the criminal has handled, and most people believe that the perpetrator of the crime can be identified, by reference to these prints, simply by looking through the files. This is not so. If an individual is to be found in a big 10-finger filing system, we must have prints of all 10 fingers. On the other hand, to identify a finger which has touched a glass and left a print on it, one has simply to compare the print and the finger; very often the identification is a mere formality. For this to be feasible, however, we must suspect a particular individual and have his fingerprint card. Comparison of each of the prints on the card with that found at the scene of the crime will enable us to say whether the latter was made by one of the fingers on the card. There are also single-finger filing systems from which, in certain cases, an offender can be traced by the ridge marks he may have left at the scene of the crime.

PHOTOGRAPHY

Criminals leave behind them not only their fingerprints but also many other material traces which, if properly collected, studied and interpreted, may enable us to reconstruct events exactly as they happened and to identify the person responsible. This principle is the very foundation of scientific detection, and the first function of this science is to discover such traces and study them in the laboratory, in order that they may be used in evidence.

First and foremost, the state of the scene of the crime immediately after the event must be permanently recorded, and for this purpose photography is naturally used. The importance of the documentary evidence thus obtained is well illustrated by the following example.

A murder is committed, the victim being killed by two bullets in the head. Our service is not informed until the following day, when it takes photographs of the scene of the crime. No trace of a bullet can be seen. A week later, in company with the examining magistrate, the men of our service work out from the prints the various stages in the tragedy, determining how the murderer fired the two shots. They return to the scene of the crime a few days afterwards to complete their observations and draw a full plan. They then note, on one of the photographs taken that day, that there is, in the room in which the tragedy occurred, a chair which had not previously been there. On that chair, which had been deliberately removed immediately after the murder, they find traces of the passage of a projectile. These marks make it possible to show that the murderer's statements during the reconstruction of the crime were untrue, and to establish how the events actually occurred.

The scene of a crime cannot, however, be photographed in the same way as for ordinary purposes; and ordinary cameras are quite inadequate. The scenes of crimes vary so much, are so differently lighted, and so different in size, that photographers and camera manufacturers have to satisfy unusual and sometimes conflicting demands. The need to use the photographs, or some of them, as evidence at a later date makes it essential that all the details shall be sufficiently clearly defined to allow of considerable enlargement.

All advances in the technique of lighting make the work of the police easier; and the development of suitable cameras and lenses gives rise to very complicated problems. Difficult research has been necessary to secure lenses with an angle of field greater than 90°, an adequate relative aperture, and a suitable depth of field.

If the photographic document is to do all that is required of it, we must be able, with its help, to reconstruct the dimensions of the objects shown in it. Since 1903, when Bertillon first devised a camera and a method of reconstruction intended for use at the scene of crimes, several not entirely satisfactory ways of solving this problem have been suggested. It was never fully solved until the progress of stereo-photogrammetry furnished the photographer with cameras and plotting devices suitable for detective work. The Swiss police are equipped with stereo-photogrammeters and automatic plotting devices (autographs); these are extremely useful, particularly in cases of motor accidents, for they make it possible, with only two photographs, to reconstruct a complete plan of the scene, showing measurements, the position of the vehicles, any marks on the ground, etc.

Even without using complicated and expensive autographs, it is possible, by more or less simple methods of geometrical reconstruction, to work out the measurements of traces found on the ground or on walls.

The author of an advertising leaflet reproduced in it a photograph of a building and he claimed that it was a nursing home in which he cured cancer by a special method of his own. On the façade of the building, there was an enormous inscription confirming his claim. Was the picture faked and had the inscription been added to the negative for propaganda purposes? The perspective naturally altered the shape of the house, and direct examination of the inscription told nothing. It was therefore necessary to plot the inscription as it would have appeared if it had been painted on a surface parallel to the photographic plate. This was done by geometric methods and it was then found, in enlargements, that the letters were so arranged that no painter could ever have done the work. The photograph was therefore faked, and there had been no such inscription on the building at the time it was photographed.

In certain exceptional cases, photographic conditions are such that aerial photography has to be employed. This is particularly useful in the case of large-scale disturbances on the public highway.

Lastly, the development of motion pictures was bound to lead scientific police investigators to try to adapt this technique to the recording of particulars at the scene of the event. The first pictures of this type were probably made in Brazil. While their usefulness may seem questionable when it is simply a case of noting facts, they are undoubtedly a great help in the reconstruction of events where the investigator is faced with several different possibilities. This system has not yet come into general use, but there is no doubt that its advantages will one day be acknowledged to outweigh its drawbacks, the most material of which is the difficulty of showing a film in court.

DEVELOPMENT OF METHODS OF SCIENTIFIC DETECTION—A FEW EXAMPLES

It is impossible, in this article, to give a detailed account of the present methods used in scientific detection. In any case, it is preferable to show how they have developed and to indicate in a certain number of cases, by actual examples, how they have been evolved and how the pure and applied sciences have helped.

First and foremost, we must emphasize the need for the forensic scientist to adapt the methods of pure science to the particular aim he has to achieve. Forensic science investigations, indeed, involve a number of requirements, some of which are very exacting, regarding the quantity of a substance to be analysed, the time taken for the analysis, or even the conditions in which the analysis itself is conducted. These requirements must be observed and the methods of pure science and technology, which have been developed to meet quite different purposes, must be adapted accordingly.

One of the most typical examples of the application of the latest scientific methods in the forensic field is that of the discovery of arsenic administered with criminal intent. As we have already mentioned, chemical methods developed during the second half of the nineteenth century and improved at the beginning of the twentieth are giving more and more reliable results. Sensitive as these methods are, however, they all necessitate the taking of fairly large samples from the organs. It is known that arsenic tends to accumulate in the hair and nails; the quantity of arsenic found in a tuft of hair, at a given point, enables us to ascertain the time when the poison was administered, since we know the speed at which the hair grows (slightly over half an inch in a month). The chemical methods previously available, however, necessitated considerable quantities of hair, from half an inch to a few inches long, and therefore covering a period of one or more months. The development of atomic piles has now provided toxicologists with a neat, and infinitely more accurate, means of tracing acute or chronic arsenical poisoning. This method, as described by Griffon and Barbaud, consists in

rendering the arsenic contained in the substance of the hair itself artificially radio-active, by exposing the hair to the flux of thermic neutrons produced by an atomic pile. Subsequent analysis of the radiation from the hair enables us, firstly, to identify the element by measuring its period and, secondly, to determine its situation in relation to the length of the hair. It is thus possible, without in any way damaging the sample taken from the living or the dead body, to ascertain the date at which the poison was absorbed, and to trace the course of its impregnation of the organism.

Such developments are very common in forensic science investigation. We have been able to identify blood for a long time past; but since micro-spectroscopes have been introduced and improved, we have been able to identify extremely small quantities (much less than a milligram) with absolute certainty. It is useful, of course, to know that a stain has been made by human blood, but that does not tell us whose blood it is. Is it possible to discover individual characteristics in the blood by which we can answer this question? The research done, over the past 15 years, on blood groups has been the first step towards the solution of this problem. When these methods are applied to dry bloodstains, they help us to decide whether a stain found on the clothing of an accused person may have come from the victim or from the accused himself.

The research done on the theory of blood groups in human beings has revealed an ever increasing number of specific factors in the blood, which are inherited according to Mendelian laws. Up to last year, the only blood groups covered by the methods of investigation used on dry bloodstains were the classic A, B and O groups. Quite recently, similar methods have been applied to the Rh factor, and there is little doubt that in future they will be applied in many other ways.

When scientific methods are introduced, the provisions of a penal or a civil code, drawn up at a time when such ideas were entirely unknown, may become outdated. For instance, under the *Code Civil,* in France at least, it was strictly laid down that only five types of evidence could be admitted in an action for affiliation. Judges, however, have become aware of the progress of research on blood groups and more and more often call evidence on that point, the importance of which is increasing daily as the number of blood groups known to us extends and the possibility of ruling out paternity becomes more definite.

The social implications of this development can clearly be seen. In certain countries, such as Germany, affiliation does not entail the obligations imposed by French law. The child, for instance, does not bear its father's name or have a claim to share in the inheritance of his estate. In France, on the other hand, a child thus recognized enjoys all the rights of legitimate children. The extension of scientific proofs may therefore have important social implications from the point of view of the father or mother as well as from

that of the child. We have come across actions for affiliation in which two men claimed to be the father of the same child.

So far, blood groups have been used mainly to rule out the possibility of a man's being the father of a child. That is the only case in which the blood group provides definite proof. Research is proceeding so fast, however, that it is to be expected that it will one day be possible to state a presumption of paternity with a relatively small percentage of error. Many young men will then have to reckon with the social implications of such actions, and the laws may possibly have to be altered as a result.

The same development can be seen in the detection of other stains of biological origin, such as semen, saliva, urine, and body fluids of all sorts. One of the main difficulties confronting a scientific investigator in the study of such stains is that of discovering them in the first place. There was absolutely no means of detecting them with certainty on a thick, coloured material until the Wood ultra-violet lamp, with its nickel glass filter, made it easy to detect the fluorescence of the stains and to carry out the necessary histological or chemical tests on the stained portions only. The substances are later identified by the classic techniques of histology, pathological anatomy and immunology.

These same methods may be applied to all animal and vegetable remains (such as wood fragments, scraps of plants or seeds, pollen, etc.) which may be discovered in dust. Every advance in these sciences makes it easier to carry out this particularly difficult type of identification. Even bacteriology may be called into play, and the following case affords a typical example.

After a big robbery, searches were made at the homes of various suspect individuals and bank notes were seized from several of these people. Expert examination showed that all these notes looked the same, having the same unusual patches of fluorescence and similar rust stains. Moreover, examination of their microscopic flora showed that the same bacteria and fungoid growths were present on all of them; in particular, all were considerably affected by a rare and highly individual fungus, *Acrostalagmus cinnabarinus Corda*. The flora on other notes kept in bundles or put into circulation was quite different. It was thus possible to prove the common origin of the notes and to confirm the complicity of the receivers.

The advances of science do not always, however, make the expert's task easier. Sometimes they make it much more complicated. We may have a police laboratory which is perfectly familiar with the methods of studying the usual textiles. Its members may be expert in comparing the fibres of wool, cotton, silk, jute, hemp, linen, etc. But the introduction of many synthetic textile fibres, to which the familiar techniques can no longer be applied, raises new problems which are sometimes extremely difficult to solve. The same is true of artificial dyestuffs, the number of which is increasing daily,

and of the countless pharmaceutical products, some of which are dangerous narcotics, capable of being used instead of the derivatives of opium or coca. Their identification involves knowledge not only of their formula and chemical properties but also of the methods of organic chemistry by which their chemical functions can be determined and identified.

One of the most striking features of this development in methods is the substitution, for visual examination, of more complicated but also more efficient techniques. For a long time, materials, textiles, fibres, threads, animal and vegetable remains, and dust were examined by means of the magnifying glass and the microscope. But such visual examination, and the interpretation of what is seen, necessarily depend on the observer. Whenever it is possible to use a physical or chemical method instead of, or to supplement, visual observation, greater precision and certainty are ensured. Mineral dust, earth and mud can be identified under the microscope; and the use of a polarizing microscope is in itself a great step forward. Lastly, the methods of mineralogical analysis—separation by increasing densities, thermal analysis by the methods of Saladin and Le Châtelier, or even the determination of the magnetic moment—are still more efficient. More recently, X-ray spectrography, by which crystalline structure can be determined, and the electronic microscope with very high resolving power have been used with great success in the identification of dusts.

In the past, the only means of studying bones was by histological examination, which revealed changes attributable to fossilization. Fossilization can be followed still more accurately by means of chemical analysis and, more particularly, by the quantity of fluorine which, in bony carbonate-apatites, gradually replaces the phosphoric acid of the phosphates. Finally, our knowledge of isotopes has very recently made an extremely useful contribution to the study of fossilization by means of the quantity of the radio-active carbon isotope (C_{14}) in the carbonates of the bones. During life, the proportion of radio-active carbon in the bones (as, incidentally, in plants) is the same as in the carbon dioxide in the atmosphere. After death, and when the body is buried in the ground, this radio-active carbon spontaneously disintegrates, half of it disappearing in about 5,600 years. By determining the remaining radio-activity of a fossil bone, therefore, we can date it with a very close approximation to accuracy. The amount of C_{14} in the wood of the funeral barge of Sesostris, for instance, which was thought to be 3,792 years old (to within 50 years either way), made it possible to establish that the barge was approximately 3,700 years old.

When a tiny fragment of paint from a broken door is found on a burglar's jemmy, we have, if we are to establish definitely that the jemmy in question was actually in contact with the door it was used to break open, to make a comparative analysis of the scrap of paint on the jemmy and the paint on the

door. Microscopic examination is of no use in this case, the only valid proof being the identification of the paint's ingredients. Unfortunately, the qualitative composition of most ordinary paints is very similar. Quantitative analysis is therefore necessary, sometimes on a sample weighing only a few tenths of a milligram. Spectrography is the only possible means we can use, and even that must be conducted under very strict control.

The expert examination of works of art is much in the public eye. Police laboratories are more and more often consulted during judicial enquiries to establish whether or not such works are genuine. The increasing number of forgeries, the skill with which they are made, and the threat they constitute to our artistic heritage, necessitate the use of more and more complicated techniques for their detection.

It is exceedingly difficult to give an expert opinion on a piece of furniture. There may be, for instance, a Louis XV bureau with carved bronze ornaments, which is apparently of very great value. How can we establish whether or not it is faked? Analysis of the bronze ornaments shows that they are gilded by the mercury process commonly used in the eighteenth century, and so worked that the piece cannot possibly be a modern copy. Examination of the wood establishes that it is old and also dates from about the same period; certain later sections have been given an artificial patina. But this wood had already been used before being incorporated in the bureau, and was cut to fit the latter by means of a power saw. The piece is therefore a copy but an old copy, probably dating from the First Empire.

Or we may have a large glazed terracotta panel, attributed to Andrea della Robbia; if it is genuine it is a real museum piece. Expert examination shows, however, that the clay of which it is made is a coarse clay containing much more iron than those used in making artistic terracottas. The pigments used are indeed the same as those employed by the fifteenth-century artists, but the same ones are still used today. The patina is artificial, being produced by a varnish with a basis of linseed oil, ochre and verdigris. Finally, the panel has been broken and restored, but the restoration was done when it was still new and was strengthened by iron bars, one being made of rolled iron. But rolled iron dates from 1850 and the panel is therefore a recent forgery.

The works of art most often forged are paintings, and a wide variety of photographic and radiographic methods have to be used in their expert examination. Repainting is shown up by ultra-violet or infra-red light; X-ray photographs, for which rays of low penetrating power are used, are a still better means of discovering traces of earlier painting beneath a later layer. Pigments can be identified by micro-chemical and spectrographic analysis and, as we know the dates at which they were introduced and ceased to be used in the last 10 centuries, they give us an invaluable means of dating certain works of art.

Arson is also difficult to detect. It is, as may be imagined, extremely hard to discover the substance left by the criminal in a mass of cinders and charred fragments, especially as such substances are highly inflammable. There may, for instance, be phosphates resulting from the combustion of a phosphorus bomb, the ashes of straw used to light the fire, or traces of oil or petrol scattered about the premises. All the processes of chemical analysis are then called into play, the main difficulty being to isolate the incendiary material from the ordinary residue of combustion.

Optical Methods

Scientific detection was, at the outset, a science of observation, supplemented by photography. Bullets and cartridge cases can thus be identified, footprints, signs of housebreaking and tyre marks compared, and forgeries on documents, identity cards, postage stamps, etc., detected. Every improvement in these photographic methods means a step forward. One of the most spectacular dates from the use of the Wood lamp, already mentioned, which provokes fluorescence in a large number of substances. Under the Wood lamp, obliterations in manuscripts are revealed, as well as writing in invisible ink, and gums and waxes of differing compositions can easily be distinguished. The colours of counterfeit postage stamps, or even the gum applied to them, can be distinguished from genuine colours or gums. Infra-red photography also often shows up things which are invisible to the eye, such as the scorch marks around a hole caused by a shot fired through a piece of black clothing at close range.

About 20 years ago, manufacturers of photographic plates began to produce emulsions of varying degrees of chromatic sensitivity, covering the whole spectrum. By using coloured screens it is thus possible to take the colours out of an object; the slightest cancellation mark on a stamp which has already been used is then clearly revealed. Here again, advances in physics have affected criminal investigation.

We are now able to make screens by which the 2,500-Angström band of mercury in the ultra-violet can be isolated. Photographs of objects taken in this light reveal certain details which are otherwise invisible. As regards infra-red light, the electronic telescope—an improvement upon the image-converting cell developed during the war to enable fighting forces to see at night time their opponents lit up by infra-red light which is invisible to the human eye—has quite recently been adapted in Belgium for use in forensic science investigation.

Some objects whose surface requires to be photographed reflect light so strongly that it is impossible to photograph them directly. This applies to carbon papers which have been used in typing a document. Their shiny surface is dulled where the characters of the machine have struck the paper.

When we try to photograph them, however, we find it impossible because of the reflection, particularly as they are very often crumpled. It is necessary to incline the surface at an angle to the axis of the lens so that the reflection is eliminated. The resulting photographs are distorted, however, and the original can be reconstructed only if we know the angle of inclination of the document; incidentally, the angle cannot be chosen haphazard but must be calculated mathematically beforehand.

The tri-chromatic selection of colours on which colour printing is based is far from perfect. It is very often impossible to cancel out a colour completely, especially when it contains white or black, which is generally the case. It is still less possible to eliminate black characters on a coloured background by photographic means, but it can in fact be done by the process described as "superimposing positives and negatives", as the following example shows.

A registered letter is handed in to a Post Office bearing stamps already cancelled but with the postmarks almost invisible. In order to ensure that these marks are not discovered, the Post Office clerk, who is involved in the fraud, stamps several times over each of the stamps. How can we discover whether, when the envelope was put into the post, the stamps were or were not already postmarked? The colours of the stamps can easily be screened out by a simple selection of colours, leaving only the postmarks; but, even in enlargements, it is impossible to discern whether or not there are other marks from different stampings among the stamp marks of the despatching office. In such a case, we may photograph on transparent films: (a) the stamp of the despatching office as a positive; (b) the postmarks on the stamps as a negative. We may then superimpose the positive and negative exactly and, if the values of the whites and blacks are exactly the same on the positive and the negative, the whites will compensate the blacks and vice versa. If we then make a print through these superimposed films, all that will show are the cancelling marks not belonging to the despatching office. It is thus possible not only to detect these traces, but partially to decipher them, and so discover the office responsible for the first cancellation.

This method, which theoretically is very simple, is in practice extremely difficult to use, for the perfect compensation of the whites and blacks presents us with a problem of photographic photometry whose difficulties are well known.

The study of written documents is still more difficult. Any treatise on scientific detection, even of recent date, will show how scanty the means employed by the experts are. They generally consist simply of examination under the microscope and the application of a few chemical reagents. More accurate methods exist, but they are much more difficult to use and involve a full-scale physical laboratory. For instance, the mineral constituents or indeed, in some cases, mineral impurities in ink can easily be identified by

spectrography. Spectrophotometric analysis of the pigments in inks enables one ink to be compared with another; indeed, a method of photographic photometry has been invented which can be used directly by reflection on the document itself. It is easy to determine the amount of iron in inks once it has been transformed into a coloured compound. Variations in the amount of iron in inks containing log-wood dyes are particularly significant, as these inks do not normally contain this product.

It seems probable, however, that the best methods of identifying and comparing the pigments in inks are chromatography on alumina, selective chromatography on paper, and micro-electrophoresis on paper, the last of which is still being tested in my laboratory. By these methods, with only one word as a test basis, the pigments in inks can be distinguished and their impurities revealed. Here again, however, progress has complicated the expert's work. The inks used in ball-point pens are very different from the earlier ones and cannot be analysed by the same methods. As a result of their introduction, therefore, the expert finds new problems facing him, and new methods have had to be devised to solve them.

Examination of Firearms

There have been similar developments with regard to firearms. Scrutiny under the magnifying glass or the microscope is still the main means of identifying bullets and cartridge cases; but we are now able to analyse, by chemical means, the traces of powder and its combustion products in the barrel of a gun or around the hole made by a projectile. Quantitative spectrography or microchemical analysis enable us to detect, in such holes, the few thousandths of a milligram of metal left behind by the bullet as it passes through the material. When this degree of accuracy is called for, absolute reliability in the physical or chemical methods used is essential. A microchemical reaction of mercury, for instance, which is very specific, will detect less than one-millionth of a milligram of mercury. By this means we can trace the mercury derived from the fulminate of a cartridge cap to a distance of more than 30 inches from the mouth of the barrel of a weapon. The following is a very interesting instance of the use of this method.

A man is found dead in bed with two bullet wounds—one in the heart, from which he must have died almost immediately, and the other a mere flesh wound in the abdomen. The weapon lies at the foot of the bed, the last cartridge fired being jammed in the ejection opening; the other cartridge is found on the ground. The first investigators, when collecting the cartridges, have mixed them up so that it is no longer possible to say which was jammed in the weapon and was therefore the last fired. The two bullets are found during the autopsy and it is easy to determine which came from which cartridge case, since one is of American and the other of Belgian manu-

facture. What the investigators have to determine, however, is the order in which the two shots were fired. In the case of a suicide, the fatal shot could only be the second; if the fatal shot was the first, it was obviously not a case of suicide, since the man could hardly kill himself before wounding himself.

In an attempt to identify the cartridge first fired, we investigated the mercury in the barrel of the weapon. As we have just said, one of the cartridges was of American origin, and we verified that the cartridge caps of this type of ammunition were made of lead nitride. The other cartridge, which was of Belgian make, had a fulminate of mercury cap. Comparative experiments showed that, if two shots were fired from the same weapon, using one cartridge with a lead nitride cap and one with a fulminate of mercury cap, the quantity of mercury found in the barrel was much greater when the fulminate cartridge was fired last. We were thus able to reconstruct what had happened and to show that the fatal shot was indeed the first, so that suicide was almost excluded.

We could quote many other examples. The one we have given shows that we should always try to solve a scientific problem of detection, even when it seems insoluble, so long as a sufficiently sensitive and specific method of analysis is available.

In the scientific detection of crime, we are therefore constantly on the look-out for new methods developed in pure science laboratories. It may with good reason be said that the development of a new technique, such as chromatography, may offer the forensic scientist unsuspected opportunities.

THE SOCIAL VALUE OF SCIENTIFIC CRIMINAL INVESTIGATION

For a magistrate enlisting the services of an expert, there is one question of overriding importance: how far can he rely on scientific evidence? His knowledge of science being naturally limited, he cannot estimate the reliability of such evidence, and the disputes which sometimes arise between experts lead him to adopt a cautious attitude.

Scientific criminal investigation produces absolute proof only in certain special cases, such as that of fingerprints; the exact value of this form of evidence can be worked out mathematically. Generally, however, this is not so.

What forensic science methods contribute to court proceedings is circumstantial evidence, often very conclusive, and, in a great many cases, sufficient to elicit a confession. Such a confession, which salves the judge's conscience, is far more valuable than any obtained in the course of an interrogation. It proceeds from a sequence of irrefutable facts, which enmesh the accused and leave him no loophole. Even when the circumstantial evidence produced by an expert does not elicit a confession, it is sufficiently precise to enable the

value of the charges brought against the accused, or the facts militating in his favour, to be weighed with considerable accuracy. The ideal system, of course, would be to express that value in mathematical terms, as is done for fingerprints. That is possible only in a few cases, but it is to be hoped that their number will increase as forensic science methods improve.

There is no doubt that the introduction of more and more accurate methods in the detection of crime makes for greater certainty in the administration of justice. The social importance of these methods is therefore clear.

Crime represents a threat to man's safety in communal life, and everything which facilitates the discovery and punishment of crime affects that safety. The introduction of scientific methods is therefore directly connected with the protection of society, and any method which adds to the resources at society's disposal influences the outcome of the struggle. Society's fight against the criminal classes may be compared to a war between two states. If one of them has greater scientific resources, it can be sure of superiority over its enemy; the same applies to the struggle against crime, and this social aspect of the question is indeed so clear that it seems unnecessary to dwell on it longer.

We may ask therefore whether the increasing armoury of scientific resources commanded by society in this struggle influences the spread or the reduction of crime.

Such an influence is obvious in a few special cases. The progress of toxicology has certainly played a great part in reducing the number of poison cases. Although we have no exact statistics going back several centuries, it is probable that poisoning was once much more common than it is at present. In our time, it rarely occurs except among the less civilized sections of the population, or in country districts. The merest suspicion of poisoning will cause it to be brought to light.

On the other hand, such social repercussions are less certain where other types of crime are concerned. The seriousness of the penalties has no real influence on the development of criminal tendencies; these must be regarded as the outcome of a man's development, and the important thing is to prevent the type of development which makes a man a criminal.

Scientific methods of controlling crime have an effect on social life in another respect—the prevention of unlawful acts. Criminal investigation laboratories are often asked to place their methods and experience at the service of organizations seeking to protect themselves against the risks of fraud. They are consulted in this way in the matter of identity cards, passports, bank-notes, travellers' cheques, and bonds. The better safeguarding of these documents makes their falsification more difficult and thus directly reduces incentive to crime. This is a new feature of the work of these laboratories, which will become steadily more important as scientific knowledge advances.

We have sought, in this paper, to show how scientific criminal investigation is revolutionizing the system of proof, which is the basis of all social law. One day, perhaps, scientific evidence of facts will almost entirely take the place of the unreliable evidence of men, so that justice will better fulfil its social function. That day, however, is still far off—for man's development, like that of things, is bound to be slow and gradual.

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NEW TRENDS IN THE SOCIOLOGY OF INVENTION: KNOW-HOW V. PATENT

by

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From time immemorial inventions have been a great social force. The horse-collar, gunpowder, the compass, movable printing type, etc., have resulted in far-reaching changes in the pattern of civilization. Up to the nineteenth century, however, inventions were few and far between, and the social changes they produced were a slow process, generally extending over a long period of time. Gunpowder, for instance, made its appearance in Europe early in the fourteenth century; but artillery was not used as the dominant weapon until the siege of Constantinople, some 150 years later, and fire-arms continued to undergo adaptation for another two centuries, until the end of the Thirty Years War. Similarly, the compass was known in Europe, in a rather primitive form, at least two or three hundred years before it became one of the main instruments of the great geographical revolution towards the end of the fifteenth century.

It was not until the nineteenth century that inventions really began to revolutionize, at an ever-increasing pace, the whole political, economic and social structure. The obvious reason was the emergence of technology. Technology was what made the nineteenth century so entirely novel and unique, so unlike all the centuries that had gone before. As Whitehead remarks, "the greatest invention of the nineteenth century was the invention of the method of invention . . . that is the real novelty, which has broken up the foundations of the old civilization".[1] This statement is not entirely accurate, as we are still far from having probed the psychological and social mechanism of invention; but it is true in that we have, undoubtedly, brought about conditions conducive to an enormous increase of inventions.

One of the most important of these conditions relates to the legal provisions governing the ownership and use of inventions. Such provisions came into existence in the early seventeenth century, but only with the birth of technology in the nineteenth century did they attain their real social

1. A. N. Whitehead, *Science and the Modern World*, Cambridge University Press, London, 1926, Chapter VI.

significance. Indeed, the Industrial Revolution with all its political, economic and social consequences is hardly conceivable without this legal device that goes by the name of "patent". But though, for a century and a half, the patent was essential to technical and industrial progress, its heyday now seems to be past. Its place is gradually being taken by something more in line with the technical requirements and social trends of our age—the know-how.

THE CONCEPT OF PATENTS

The concept of patents goes back to the early seventeenth century—to the Statute of Monopolies of James I of England. This statute, promulgated in 1623, was designed to abolish the privileges and monopolies which were current at that time and were regarded as a veritable social scourge. It declared all monopolies null and void, with the exception of letters patent and privileges granted to the inventors of new products or manufactures, but "so as also they be not contrary to the law nor mischievous to the State by raising of the prices of commodities at home or hurt of trade or generally inconvenient". This definition is still, to a large extent, the guiding principle of all patent legislation.

It is interesting to note that the concept of a patent was not entirely divorced from theological considerations. The idea of patents arose in England at a time when the law was particularly strictly directed against witchcraft; and it also reflected a reaction against alchemy. Any inventor publicly revealing his secret thereby showed that he had not concluded a pact with the powers of darkness. Thus Neper, the inventor of the logarithms that bear his name, wrote on the first page of his book (published in Latin in 1614): "This miraculous means of making calculations was worked out with the authorization of our Holy Mother the Church."

Outside England, however, it was not until towards the end of the eighteenth century that patent legislation made its appearance in the leading countries. In the United States of America, it is a direct outcome of the 1787 Constitution, Article I, Section 8, Clause 8 of which made formal provision for patents. A Bill on this subject, very largely modelled on the English system, was enacted in 1790. In France, patent legislation was instituted with the law of 1791. Under the old régime, the king, at his pleasure, granted letters patent to inventors. In Germany, the first patent laws appeared in certain States as early as 1815, but it was not until the Zollverein Convention of 1842 that the principles of an overall German law were laid down. The other countries adopted similar laws, based on the three main systems in force: Anglo-Saxon law is applied, with certain modifications, by all countries of the British Commonwealth; the German system influences the

Scandinavian countries, the Netherlands, Austria and Hungary; while French law guides all countries that have adopted the Civil Code.

Generally speaking, the patent was at the outset, and still is, a kind of contract between the inventor and society. The inventor discloses to society the secret of how to work his invention, and society, in exchange, undertakes to reserve for the inventor or his beneficiaries a monopoly in the working of his invention for a period varying, according to the country, from 15 to 20 years. Even today this period is an appreciable fraction of human life; it represented a much larger fraction at the time when patent legislation was beginning to evolve. In brief, the law is based on the principle that society grants the inventor an exclusive privilege or monopoly solely because of the value, to society, of his invention. The obvious corollary is that, if that value to society is for any reason impaired, the monopoly granted to the inventor ceases to be justified. As we shall see later, it is the interpretation, in a particular way, of this principle which is basically responsible for the present depreciation in the value of patents.

In fact, the present-day concept of the social utility of patents is somewhat akin to that which inspired the drafting of Anglo-Saxon legislation, namely that the patent was a monopoly and, as such, was to be regarded with disfavour by the law. But in the nineteenth century this concept had made way for the French thesis that the inventor's right was a natural right, and for the German idea that the patent was in some sort a bargain concluded between the inventor and society.

It should also be noted that the conditions governing the issue of patents vary considerably from one country to another. In France, and in countries which have adopted the French system, the patent is issued without any previous examination of the scientific value or novelty of the invention, and hence without any guarantee from the government (S.G.D.G.).[1] Great Britain and many of the Commonwealth countries make a point of carrying out some limited investigation into the novelty of the invention and of ensuring that the text describing it is clear. But it was to German patents, and quite rightly, that the greatest prestige attached. Apart from the question of novelty, the German Patentamt introduced the concept of the scientific value of the invention, implying a preliminary investigation of its practicability. Admittedly, the examiners in the Patentamt were not infallible; Bessemer's application for a patent for his converter was rejected on the grounds that his invention was impracticable, Giffard's for the steering of balloons was refused on the grounds that the invention was not serious, and Oberth's for the space ship for interplanetary travel met a similar fate on the grounds that the invention lacked novelty. But apart from these very few human

1. Cf. Jean Pouillet, *Traité des Brevets d'Invention*, Billard, Paris, 1879. (S.G.D.G., sans garantie du gouvernement.)

errors, the German examiners, thanks to their admirable analyses and their full bibliographies, have rendered invaluable service to thousands of inventors and industrialists and to the cause of science and technology in general. To obtain a full bibliography on any given subject, it became customary to apply for a German patent on that subject.

The American patent enjoys the same sort of prestige as the German patent. It is not granted until the novelty of the invention has been investigated; and the extensiveness of the research carried out in this connexion is well known—as is also its slowness, which is deplored by inventors throughout the world. The vast library of the Patent Office comprises, among other things, all the scientific fiction magazines that might possibly be taken into account in connexion with the issue of patents. Thus the periscope was regarded as a non-patentable invention because Jules Verne had described it in *Twenty Thousand Leagues under the Sea;* and it is not impossible that science fiction articles may one day be used as grounds upon which to reject applications for patents on interplanetary navigation, for instance. But the American patent also involves a very extensive legal analysis; its claims define with the utmost precision the nature of the invention and the particular rights granted to the inventor; they are a remarkable blend of abstract and concrete, of ideas and facts. American legislation is also more favourable than most other systems to the individual inventor, who often lacks financial resources. In particular, it is the only system under which a single fee is charged, whereas in most other countries the inventor has to pay annual instalments, generally at an increasing rate. This latter procedure is extremely unfair to the inventor, who often needs several years in which to make his invention a paying proposition. Very frequently a French or English inventor loses his patent at the very moment when he reaches his goal, through inability to pay the annual instalments. Another special feature of the American patent is the fact that it is issued only to the inventor himself, who often makes a statement before witnesses as soon as he has thought out the invention and well before the application for the patent is filed.[1]

Of the other examining offices, special mention should be made of the Swiss office (where Albert Einstein was once an examiner) and of the Swedish and Netherlands offices. At the international level, co-operation between the leading countries was established by the International Convention for the Protection of Industrial Property, signed in 1883 and in force since 1884. This convention safeguards, through the first patent taken out in one of the member countries, the inventor's right of priority in all other signatory states for a period of one year. This obviously does not relieve the inventor of the need to take out a patent in each country where he wishes to safe-

1. On the subject of American patents, see Karl Michaelis, *Praktisches Handbuch des Amerikanischen Patentrechts,* Carl Heymans Verlag, Berlin, 1932.

guard his rights; and this requirement, which involves heavy expenditure, has led to the idea of an international patent. An instrument for carrying this idea into practice already exists in the shape of the International Bureau of the International Union for the Protection of Industrial Property, set up in Berne under the 1883 convention, which now has a membership of some 40 countries, including all industrial countries except the U.S.S.R. However, the international patent seems unlikely to be instituted in the near future.

THE HEYDAY OF THE PATENT

With the progress of legislation during the nineteenth century, patents, especially those delivered after examination, acquired considerable importance in the business and industrial world. With the help of key patents, many industrial groups were able to acquire a world monopoly in the manufacture of certain equipment or products. The electric filament invented by Edison, De Forest's three-electrode lamp, Bessemer and open hearth steels, Whitney's loom and McCormick's harvester are instances in point. The patent gradually became one of the classic means of acquiring a monopoly, especially in the Anglo-Saxon countries, where common law was particularly severe upon purely economic monopolies. Private inventors occasionally managed to cover an immense field with their patents. The American Carleton Ellis, for instance, took out 810 patents, none of them without value. To him we owe such inventions as quick-drying paints and varnishes, which play so great a part in the automobile industry; nine-tenths of the plastics now in use; methods of improving edible oils; methods of cracking petroleum, and so on. His first patent was taken out in 1900; his last in 1940, at which time he, as an individual, held the record for the number of patents in industrial use. Since the defeat of Germany, the world has learned that over 1,000 patents filed in the name of I.G. Farbenindustrie and used throughout the world were the work of a single man, Dr. Walther Reppe.

The prestige and dignity attaching to patents in the second half of the nineteenth century and the first quarter of the twentieth can hardly be imagined today. The establishment of the Patentamt in 1877 was regarded as a landmark in German history; and Dr. Carl Duisberg, who founded the I.G. Farbenindustrie in 1925, looked upon German patent legislation as one of the country's main sources of wealth. The patent was a title whose value and validity few people dreamt of disputing. Inventors refusing to take out a patent for the better guarding of their secret belonged to the world of popular novels rather than to the world of reality. Few actions were brought for infringement or invalidity. The best illustration of this state of mind is perhaps the attitude of the belligerent countries towards patents in the 1914-18 war; patent offices continued to examine, with great impartiality,

applications filed by enemy nationals, and special measures were taken, in co-operation with neutral countries, to prevent any interruption in the payment of annual instalments.

In various countries, the agencies responsible for the administration of enemy property had to undertake the working of enemy patents. In particular, the United States of America, with its (at that time) relatively small chemical industry and almost total lack of large organic-chemical industries, had, during the war, to take over 12,000 American patents (5,000 of them in the realm of chemistry) belonging to German nationals. A special company, the Chemical Foundation, was established to buy back the patents seized by the Alien Property Custodian, and to work them. This is the origin of the leading organic-chemical industries, such as the dyestuffs industry, in the United States of America, and it is from this period that the country's large-scale chemical industrial expansion dates.

All these factors still further increased the importance attached to patents. It was generally thought, at the time, that even discoveries concerning aviation or atomic energy would be patented. It should be borne in mind that in 1919 atomic energy was already entering into the realm of possibility: Aston, Soddy and other contemporary scientists were publicly stating their belief that the energy stored within the atom would soon be released, and H. G. Wells, in his book *The World Set Free,* described a suit for infringement involving a public discussion of atomic energy problems. It is significant that in 1919 Professor Robert H. Goddard took out the essential patents for jet propulsion, covering, among other things, the jet rocket from which the German V.2 bomb was derived. Such an attitude would appear inconceivable today, so accustomed have we grown to the idea of inventions as a secret, and of inventions as the property of the state, whereas a patent was by definition a contract between the state and the inventor.

In 1920, however, it is our present ideas that would have seemed inconceivable. The patent was then surrounded by an aura of romance that was frequently conjured up in books and films of the day. In short, it appeared to be one of the firmest bases of technical and industrial civilization. Yet the first signs of the patent's eclipse could already be discerned.

THE DEPRECIATION IN THE VALUE OF THE PATENT

The depreciation in the value of the patent is mainly due to two groups of factors—scientific and technical on the one hand, and social on the other.

The origin of this development must first be sought in scientific and technical progress. The growth of parallel techniques for achieving the same result means that the same ends can be attained by several different means. Thus, to examine an object without destroying it, use can be made of

magnetism, the electro-magnetic field, X-rays, gamma rays, neutrons, and so on. In other words, modern technology usually provides a way of circumventing a patent, or "slipping through" a series of patents designed to cover a whole field so as to discourage other inventors. For instance, when the property of copper oxide of converting alternating into direct current was discovered, a leading American company patented the utilization of all oxides and halogenides of all metals—which meant an enormous number of patents. However, an inventor sidestepped this obstruction by using silicon, which is not strictly speaking a metal. Similarly, any patents on amplifiers using complex assemblies of electronic valves were completely by-passed by the invention of electron multipliers. In short, with the progress of technology, it has now become far easier to circumvent a patent—and this, obviously, is not calculated to raise the prestige of the patent system.

Another important result of technological progress, so far as patents are concerned, is the increasing complexity of the techniques themselves. Some modern processes are so complicated that it is virtually impossible to describe in the form of a patent or written specifications the exact method of carrying them out. It often happens that a company selling or transferring a patent or process to another firm despatches, at the same time, a team of technicians who are responsible not only for the starting of the operations but for the actual manufacture of the product in question, sometimes for a period of several years, until the technicians of the firm purchasing the process have gained sufficient experience in its application. In other words, the actual acquisition of a patent does not give the purchaser any guarantee of being able to work the invention. This is a relatively new factor, which is the direct outcome of the growing complexity of modern technology and was not, or was barely, operative 30 or 40 years ago.

Lastly, technical progress has had another somewhat parodoxical effect on patents, in the form of the increasing number of applications for patents which are not followed up and thus fall into the public domain. It has, in fact, become progressively more difficult to defend patents before the law courts from the strictly scientific and technical standpoint, quite apart from the social and legal aspects involved, which will be dealt with later. The reason is that such defence necessitates a thorough study of antecedents in the form of previous patents, scientific and technical publications, and sometimes even advertisements. But the vast growth of scientific and technical literature and of the number of patents filed during the first half of the twentieth century has made such a study extremely costly. Accordingly, an increasing number of applications for patents are not followed up, and the relevant inventions fall into the public domain. It is estimated that in England and the United States of America, as well as in pre-war Germany, three out of four applications for patents were allowed to lapse. Some companies have a research service specializing in this "anti-patent" work; thus, ballpoint

pens were not placed on sale until the patents for them had fallen into the public domain.

However, difficult as it now is to defend the patent at law from the purely scientific and technical standpoint, it has recently become yet more difficult to defend it on legal grounds. This is where social factors enter into the case.

It should first be stated that an action for invalidity may be brought against any patent, whether issued without examination, as in France, or after examination as in the case of English, American or German patents. In such cases, jurisprudence is often of more account than the letter of the law. But even the law is often vague and disconcerting; it hardly ever defines what *is* patentable, but is generally content to define negatively what *is not*.[1] As for jurisprudence, it is often so contradictory as to undermine the very notion of patent.[2] For instance, pure acetyl-salicylic acid (aspirin) is declared patentable in the United States of America, whereas a pure metal such as tungsten or molybdenum is not. In *Mineral Separation* v. *Hyde* the United States Supreme Court ruled that the reduction of the quantity of oil used for the floating of slimes (ore), from a few kilograms per ton to a few grammes, was patentable, because there was a difference in quality; but in *Metal Hydrides* v. *Patent Office* the same court declared that the reduction of impurities in tungsten, uranium, vanadium and thorium from a few per cent to less than a thousandth was not patentable. Furthermore, American judges are showing an increasing tendency to rule that an invention which has required many years' study and the collaboration of many scientists is non-patentable, on the grounds that there has not been "a flash of genius" and that another team of scientists would necessarily have arrived at the same result (*Cuno Engineering* v. *Patent Office,* before the United States Supreme Court). But inventions which result from a flash of genius are increasingly rare. Modern invention is essentially the result of team-work and long years of research, and firms that devote large sums of money to such research obviously do not like to be deprived of the fruit of their labours by the patent falling into the public domain.

It should further be mentioned that the courts often come up against extremely subtle technical problems. In France, for instance, there have been lawsuits where it was necessary to decide whether the use of a stereoisomer of a substance instead of the substance itself constituted an infringement, or whether the use of a magnetic field created by an electromagnet instead of a permanent magnet constituted a novelty (electrodynamic loud speaker).

It should be emphasized that the change over the past 20 or 30 years has been not so much in patent legislation as in the interpretation of that legis-

1. See Armand Picard, *Précis de Brevetabilité*, Dunod, Paris, 1928.
2. Cf. Robert Moureaux and Charles Weismann, *Les Brevets d'Invention*, Dalloz, Paris, 1926; M. Massius, *Traité des Brevets d'Invention*, Billard, Paris, 1931.

lation. Jurisprudence has always been largely dependent on social trends, and judges more often than not reflect the views of the society to which they belong. Social concepts of ownership have evolved considerably over the past 50 years. The progress of socialist ideas and the growth of state intervention in the economic field, even in countries whose ideas are not socialist, have well-nigh swept away the concept of the inviolability of private ownership so characteristic of the nineteenth century and still so deeply rooted in most countries before the second world war. In the field of invention, this trend is reflected in the growing and sometimes excessive subordination of the interests of the inventor—whether the latter be an individual or a firm—to those of society. This trend is accentuated by the general public's growing hostility towards monopolies—an understandable and almost natural reaction against the development of trusts and the abuses of monopolies between 1870 and 1930.

This tendency to break down monopolies, so characteristic of our time, is probably the most important factor in the present-day depreciation of the patent system. Public opinion demands the abolition of monopolies, and jurisprudence is obliged to follow. In England, the examination of patents is becoming more and more a mere formality. In Germany, perfectly valid patents have occasionally been invalidated for fear of displeasing public opinion. In the United States of America, the Supreme Court quite frequently invalidates patents submitted to it, for reasons often so contradictory as to have given rise to the saying that "invention, like the Constitution, is what the judges say it is".[1] Such an attitude has naturally resulted in a considerable lowering of the prestige and value of patents. Accordingly, the concept of patents has gradually given way to the concept of know-how.

THE CONCEPT OF KNOW-HOW

Know-how may be defined as the body of knowledge necessary for the effective application of a new process. In this respect the concept of know-how is in line with the original concept of patents, which, at the outset, contained all the know-how necessary for their application. But, unlike the patent, know-how brings with it no legal protection. As we shall see later, it may be kept secret or sold or transferred or disseminated free of charge, but in no case has it the legal character of the patent.

As know-how is essentially an art of reproducing, it involves an exact definition of the conditions required for working a process or obtaining a product. This definition in turn calls for precise measurements of certain

1. John C. Steadman, "Invention and Public Policy", *Law and Contemporary Problems*, XII (1947), p. 664.

properties and characteristics, and it is worth noting that the concept of know-how has necessitated the creation of new measurable properties, such as fluidity, plasticity, the rate of modulation, the purity of a signal, etc. It has also been necessary to devise new measuring instruments, such as the photocolorimeter, or to adopt new concepts (e.g. photoelasticity), on which new methods of measurement are based. It is essential to realize that know-how is something more than sleight-of-hand or a manufacturing secret; it is a scientific and extremely precise description of a usually highly complex technique, so complex that, with the best will in the world, it is generally difficult to communicate and calls for considerable scientific competence on the part of all concerned. As in the case mentioned in connexion with patents, it frequently involves despatching a team of technicians for an extended period, to familiarize the licensee with the details of the process.

Moreover, it often happens that the know-how is not accurately enough known to be communicable. In many cases, we cannot say what distinguishes a good from a bad product. A good instance is provided by battery carbons. The most delicate methods—electronic microscopes, X-ray diffraction, the diffraction of neutrons—have proved inadequate to distinguish a good carbon, which will make the battery last for years under difficult operating conditions (railway signals, automatic rural telephones), from a poor carbon which will lead to a drop in voltage after a few months. The same seems to apply to the aluminium covering of uranium bars used in atomic piles (canning). It has never proved possible to transfer the manufacture of harmonicas from Germany to France, or the manufacture of glass balls used for "cat's eyes" from Czechoslovakia to Germany. In each case there is lacking one or more of the new measurable properties capable of defining the state of the product and the know-how of its manufacture. Generally speaking, when it is said that the manufacture of a particular product is an art rather than a science, this means that it has been impossible to systematize the know-how in this field. It remains true that, when it is worth while, some means of systematizing the know-how is invariably found, as in the case of the manufacture of radar magnetrons (transfer of know-how from England to the United States of America) or of penicillin (transfer from the United States of America to the rest of the world). Most of the atomic "secrets" are extremely complex techniques which are, in fact, know-how.

KNOW-HOW—INDUSTRIAL PROPERTY

Although the know-how affords no legal protection, it is none the less a form of industrial property which, like a patent, can be negotiated. Quite often, it is the complement of a patent or of a series of patents. But whereas the acquisition of a patent gives the patentee no *technical* guarantee of being

able to work the process or manufacture the product in question, such a guarantee is, by definition, conferred by the know-how, as the latter is essentially an art of reproducing.

Unlike the patent, however, the know-how gives no *legal* guarantee against the working of the process by others who have managed, independently, to discover the technique. Yet the know-how, when sold, costs far more than the corresponding patent. When the patent alone is sold, it is customary to pay a royalty of approximately 2 per cent of the turnover; but with the sale of the patent plus the know-how, or of the know-how alone, the royalty is in the vicinity of 8 per cent. The know-how may also be sold for a lump sum; recently an American group transferred to a Turkish group, for a sum of $17,000,000, the know-how for the manufacture of fertilizers. In other cases, the know-how may be transferred in exchange for a share in the purchaser's business; this was what happened when I.G. Farbenindustrie and the Japanese Government concluded a transaction concerning the synthetic petrol plant in Manchukuo.

Know-how alone, without the corresponding patent, is sold mainly in the following cases:

1. When the patent has fallen into the public domain (as recently happened when Twentieth Century Fox bought the French "Cinemascope" or "Hypergonar" process for three-dimensional films).
2. When the patent has not been filed in the country of the licensee (a frequent case in underdeveloped countries, such as India, Pakistan, Egypt, certain Latin American states, etc.).
3. In the case of techniques which are not patentable because of their complexity or owing to legal considerations (fluorescence, manufacture of filaments for incandescent lamps, of cathodes for electronic tubes, etc.).

There is perhaps no better illustration of the present-day importance of know-how than the efforts made by the Allies, towards the end of the last war, to acquire the secrets of German and Japanese techniques. Three teams of scientists and technicians—known by their code-names Bios, Cios and Fiat—went through the Axis factories and plants and assembled all information on German and Japanese industry and technique. What was sought here was simply the know-how, as the corresponding patents were already well known. This vast body of technical information was eventually made available to the public free of charge. One only needs to order a microfilm in Paris, London or Washington to acquire, against payment of the costs of reproduction, a know-how which, before the war, would have been worth millions of dollars.

This is not the only instance in which the know-how has been handed over free of charge. Certain official bodies, like the United States Bureau of Standards or the National Research Development Corporation in Great Britain, are constantly conducting research and developing techniques whose

results are made available cost-free to interested parties. But even industrial firms occasionally find it advantageous to place the know-how of certain processes at the disposal of their competitors free of charge. As a matter of fact, in the case of a widely used product, mass manufacture by several firms creates new needs which fully warrant the free disclosure of know-how and the loss of the monopoly. In the long run, the product becomes so widely used that the firm which gave the secret away sells far more than it could have done if it had kept the monopoly. Furthermore, the disclosure of a process arouses the interest of scientists and engineers throughout the world, and encourages them to perfect the process and sell their improvements to the firm which developed the process in its original form. Thus the divulging of the secret is usually a spur to technical progress. For instance, Dupont de Nemours found it worth while to reveal the know-how of their process of manufacturing cellophane. But this has not always been the case. Until quite recently, a large European firm manufacturing pneumatic tyres used, in its workshops, thermometers graduated in X degrees and viscosimeters graduated in X units so as to prevent any leakage of know-how.

Such an attitude is becoming increasingly rare today, especially in the United States of America. The American, Frederick Lewis Allen, recently wrote in this connexion: "A prominent characteristic of modern industrial trade associations is the amount of information they collect and make available to everyone in industry. . . . One thing that almost every foreign businessman exclaims at in America is how few secrets there are."[1]

To a certain extent this new attitude is due to the motives of personal interest we have mentioned. Enlightened industrialists and businessmen find that it is often more profitable, from the purely material standpoint, to reveal their secret of manufacture than to keep it. But it is also largely due to the change in social outlook brought about by the two world wars. The action of governments against cartels, especially in the United States of America, is one of the most striking symptoms, and no month goes by without some new decision on the subject being announced. Quite recently, the United States Federal Court ordered the United Shoe Company, one of the largest firms in the world, to grant a licence of its patents to all its competitors. This decision, taken after examination of a file running to 14,194 pages and of 5,512 exhibits produced in evidence, deals the death blow to one of the world's last monopolies based on patents. A similar decision was taken with regard to the American aluminium company, Alcoa. Imperial Chemical Industries and Dupont de Nemours were also forced to dissolve their agreement, described as a cartel, and to bring close on 2,000 patents into the public domain. In Great Britain the large American firm of Parke Davis Ltd. has been ordered by a court judgment to grant the licence for a process of

1. *Life*, 26 January 1953, p. 39.

manufacturing an antibiotic to its English competitor British Drug Houses Ltd. Countless other examples of this type could be quoted.

Public opinion today reacts no less strongly against secrets in industry than against secret diplomacy. The leading companies are fully conscious of this fact, and have recently set up "public relations departments" to make the public aware of their work and their social usefulness. Some of them publish reviews containing not merely the results of scientific research but also technical details which, 20 years ago, would have been regarded as manufacturing secrets. This desire of the larger industrial firms to raise their social prestige is linked with the new trend discernible in business and industry, a trend which has been described as economic humanism.

These developments, however, do not mean that the patent has lost all its value and become an out-dated institution. But it certainly has lost the dominant position it occupied in the business and industrial world only 50 years ago. It is now being superseded by know-how, which is more in line with the technical needs and social outlook of our age.

Everything points to the probability that, in the long run, patents can only retain their legal value and practical utility if coupled with the know-how which is their indispensable corollary.

BOOKS AND PUBLICATIONS

EVOLVING A SOCIOLOGY OF SCIENCE

BARBER, Bernard, *Science and the Social Order*, with a foreword by Robert K. Merton, The Free Press, Glencoe, Ill., U.S.A., xxiii+228 pp., $4.50.

Much has been said and written in the last dozen years on the impact of science on society. But a closer examination of these writings reveals how little serious thought has been given to the study of the social aspects of science. With few exceptions, all these writings fall roughly under two distinct headings: that of popular science, and that of Marxist philosophy. The former writings take the form of articles or books which are quite often excellent and useful expositions aimed at acquainting the non-scientists with the achievements of science and their meaning in terms of everyday life; but they could hardly be said to contribute any original thought to what, for want of a better term, may be called the sociology of science. The latter appear much more serious—at least to the uninitiated—and they have a definitively sociological slant; but they also have an axe to grind, and a more careful perusal of them inevitably leaves the impression that they have been undertaken with a view not so much to studying the social aspects of science as to finding, in the field of the sociology of science, apt illustrations for the Marxist thesis. As a result, the subject is today little more advanced than it was over a century ago, when its study was first started by the newly-formed positivist school in France. Indeed, the American sociologist Edward Shils counts the study of the social aspects of science among the major undeveloped areas of sociological inquiry.

What are the reasons for this neglect?

In his excellent foreword to Dr. Barber's book, Professor Merton suggests that some of them may not be unconnected with the fact that the relations between science and society constitute a subject-matter which is close to the heart of Marxist sociology, one, moreover, which has become almost a monopoly of Marxist thinkers. This may account for a certain reluctance on the part of academic sociologists to take up the subject, not necessarily from fear of guilt by association, but rather because Marxism, unlike most other philosophies, arouses irrational feelings both of fervour and hostility, so that those who reject the philosophy also often reject with it its specific subject-matters.

This may go some way towards explaining the neglect of the study of the social aspects of science. Far more pertinent, however, appears another argument which Professor Merton mentions in passing but to which he does not give nearly enough weight: the fact that this study calls for a combination of branches of knowledge which is rarely found in one and the same person. It calls for a good knowledge of the nature of science, of its methods, and indeed of science itself, the kind of knowledge which physical and biological scientists have acquired after years of training and practical work. But it also calls for a good knowledge of all those branches of study which view

society from the angle of its economic, political, ethical and other activities, in other words for a knowledge of sociology, which too is the product of several years of study and experience. It is obvious that a combination of these two very different branches of knowledge and training in one person must necessarily be extremely rare. An exception which at once comes to mind is that of Professor Michael Polanyi, who, after distinguishing himself in the field of physical chemistry, became professor of social studies at the University of Manchester. But such exceptions are so few that they hardly offer a solution to the problem. So, in practice, the sociology of science must rely mainly on two groups of students: physical or biological scientists who, by some chance of fate, have turned to a branch of social study or have been drawn into the sphere of government or administration; and sociologists or historians who, by predilection or accident, have acquired more than a casual acquaintance with physical or biological science.

However, the scarcity of original writings on the subject shows that even in this class the number of students is very small. Until recently, it has been mainly the physical and biological scientists who have concerned themselves with the social aspects of science. According to Professor Merton, they account for some 50 per cent of the writings; a quarter only come from historians and philosophers of science, and another quarter from sociologists. But while it is true that it is the physical and biological scientists who have jerked the study of the social aspects of science into new life, it is the historians and sociologists who have provided the more valuable contributions. Works like Professor Butterfield's *The Origins of Modern Science,* or Professor Hayek's *The Counter-Revolution of Science*[1] would be difficult to match by anything that has yet come from the physical or biological scientists. Can it be that the latter find it more difficult to assimilate the methods of historical research and sociological interpretation than historians and sociologists find it to comprehend the method and workings of science? At any rate, there are unmistakable signs that historians and sociologists are taking an increasing interest in science. The reason for this newly-born interest is not far to seek: in the last dozen years science has suddenly become an urgent social problem, and as such was bound to attract the attention of historians and sociologists. Dr. Barber's book is one of the latest contributions of a sociologist to this field.

It must however be confessed that it does not fulfil the high hopes raised by its title. "Science and the Social Order" suggests an all-embracing study covering practically a whole field of the social aspects of science. Instead, we find in this volume 11 chapters, each in the form of a short essay, bearing on such subjects as the nature of science and the place of rationality in human society; the historical development of science and the social influences bearing upon it; science in modern society both liberal and authoritarian; the social organization of science in general; the social organization of science in American society, with separate chapters devoted respectively to science in the university, in industry and business, and in government; the social process of invention and discovery; the social control

1. Professor Hayek's book was reviewed at length in our last issue (Vol. IV, No. 2, Summer, 1953, pp. 119-24).

of science; and, lastly, the nature and prospects of the social sciences. All these essays taken together do not cover more than a small sector of the subject indicated by the title. Moreover, half of the book bears on the peculiar conditions of science in the United States, and this applies not only to the chapters specifically devoted to the American scene, but also to some which are not and which would have gained in value from a broader treatment. Thus the chapter on invention and discovery as a social process relates almost exclusively to American conditions, and that on the prospects of the social sciences views the problem from an angle which would not be readily accepted by some schools of thought.

True, a volume of this size could hardly be expected to deal anything like exhaustively with so large a subject. In fact, it could barely do more than set out the main problems. But this the author has not attempted. Thus the book falls between two stools; it is not comprehensive enough to be of general interest, and it is not detailed enough to attract the interest of the specialist. A subject like the social process of invention and discovery cannot but arouse a feeling of frustration in the serious reader when dealt with in no more than some 16 pages, for such a treatment can only result in the enunciation of generalities which are already fairly familiar. This is perhaps the main reproach a reviewer might make to this book. In one instance, however, the author has departed from this approach: the place of science and the scientist in American society is treated at some length in four consecutive chapters which together form over a third of the volume. And this is undoubtedly the most valuable part of the book; an accumulation of hitherto fragmentary and unco-ordinated material is here put into order to serve as a basis for a study of a particular aspect of the sociology of science. Here Dr. Barber is obviously on home ground, and one cannot help regretting that he did not devote even more space to this absorbing and rewarding subject.

There is something fascinating about the rise of science in the U.S.A., and about the sociological factors responsible for it. Only 50 years ago science in America was still in its infancy; today it is bidding for world leadership, and its achievements are second to none: "American science is riding on a steep up-curve. Everything about it has been on an exponential curve." This phenomenal rise is due mainly to the attitude of American society, which, since the end of the last century, has considered science as a major factor in national life and has steadfastly adhered to the conviction that only through research and more research could it provide the basis for an expanding economy. This attitude has permeated the universities and the sphere of government, as well as industry and business. The number of Ph.D's conferred rose from 44 in 1876 to 2,709 in 1937, while the number of conferring institutions rose during the same period from 25 to 86. The number of scientists listed in *American Men of Science* increased from 4,000 in 1903 to 34,000 in 1944. The Government is today the home of some 30,000 scientists, while industry and business have now accepted the principle that strong scientific research is good business.

Nothing perhaps better illustrates the position of science in the U.S.A. than the very high position scientists hold in the American occupational hierarchy. A survey has shown that they rank very near the top of the scale, above Congress representatives, bankers and big business executives. The same survey has also revealed that scientists, when considered in general,

enjoy a somewhat greater prestige than when they are considered as members of a specified branch of science, such as physicists, chemists or biologists; strangely enough, chemists rank higher than nuclear physicists, who in turn rank above biologists.

However, this high ranking in public esteem does not carry with it a correspondingly high social reward in the form of money income. While scientists do earn a larger average income than most other occupational groups in American society, very few individual scientists command the very large incomes enjoyed by some other occupations which rank much lower in public esteem. Few of them earn more than $20,000 a year (these are the scientists who administer big industrial research groups), and even the proportion of those earning over $10,000 a year is relatively small (11 per cent of scientists in universities, 7 per cent in government and 19 per cent in industry are in this category).

An interesting fact brought out by Dr. Barber is that American scientists do not take a very active interest in social problems, not even in those directly related to science itself. Notwithstanding the amount of discussion and literature on this subject emanating from scientific circles, the proportion of scientists who seriously concern themselves with these problems is very small—no more than a few thousand out of the estimated 750,000 scientists, engineers and technicians in the U.S.A. The Federation of Atomic Scientists, which is particularly active in this field, has seen its membership drop from some 3,000 at its commencement to no more than 1,500 in 1950. However, the relatively small group of scientists who do concern themselves with social problems raised by science has wielded an influence altogether disproportionate to its size, mainly because it counts amongst its members most of the prominent and influential scientists.

This and much other interesting information, well arranged and neatly presented, is given by the author in this part of the book, which is devoted to a sociological analysis of the place of science in American society. It deals with the pattern of co-ordination and control in American scientific activity, with the organization of science in the universities, government and industry, with such things as the class and religious backgrounds of American scientists, and with many other characteristics of science in the U.S.A. This section of the book, in fact, largely compensates for the shortcomings of other sections.

To turn to these shortcomings, few serious students of the history of science would agree with one of the basic assumptions made by Dr. Barber in tracing the historical development of science, viz. that science is not *uniquely* modern, that in this respect there has been no radical discontinuity in history, and that, for at least the last three or four thousand years, and even beyond that, the record of the evolution of science runs fairly continuously, "without unbridgeable gaps". Such an assumption may be a convenient device for a historico-sociological interpretation but, unfortunately, it does not correspond to historical fact. Of course, there was science in ancient Egypt and in ancient Greece, but this science bears as much relation to modern science as does the ancient message-bearer to modern radio communication. Between science as it existed during the millenia of recorded history preceding Copernicus and Galileo, and science as it has existed in

the few hundred years after them there is a gap as unbridgeable as can well be imagined in one and the same world. So great is it that the scientific revolution associated with the sixteenth and seventeenth centuries remains one of the great mysteries of history which still await a satisfactory explanation. It is science, and science alone, which differentiates our civilization from any other civilization that has ever existed; it is something unique in history, which has created "a civilization that could cut itself away from the Graeco-Roman heritage in general, away from Christianity itself—only too confident of its power to exist independent of anything of the kind . . . a civilization exhilaratingly new. . . ." (Butterfield).

The error in Dr. Barber's reasoning appears to arise from identifying empirical rationality with science itself. But while science cannot exist without empirical rationality, empirical rationality does not necessarily produce a scientific civilization—as is shown by the fact that empirical rationality in man goes back to the dawn of recorded history, while the scientific civilization goes back no more than a few hundred years. To make a comparison, petroleum has been under the ground for hundreds of thousands of years, and its existence has been known for at least three or four thousand years, but it is only since 1859, when it began to be extracted in large quantities and put to use, that an oil civilization came into being.

Another of Dr. Barber's assumptions which finds even less support in reality is his faith in the value of science as a force promoting rationality in other spheres of human activity:

> . . . the general liberal faith in rationality probably receives its strongest reinforcement from the continuing achievements of science. When men waver about the virtues of reason, science is a powerful and insistent reminder of its worth. We can see how this occurs even among the scientists themselves.

This rather naïve belief in the "transfer value" of rationality in science has been so much discredited that it is rather surprising to find a sociologist still clinging to it. Not only is science incapable of inspiring non-scientists with a rationality they do not already possess, but it is powerless to help scientists themselves to carry over the rational way of thinking they employ daily in their own profession to problems outside the realm of science. Bertrand Russell, who is a philosopher as well as a scientist, says that:

> Scientific method . . . is still employed only by a minority, who themselves confine its employment to a minority of the questions upon which they have opinions. The scientific attitude is in some degree unnatural to man (as shown by the attitude of the scientist himself towards politics, income tax, etc.).

And David E. Lilienthal, who, as the first chairman of the Atomic Energy Commission of the United States, had as good an opportunity as any outsider could have for observing scientists, once said that, "when a scientist goes in for political dogmatism, he can make a politician look scientific by comparison".

It may be added that, throughout the book, the term "science" refers to the natural sciences only. This undoubtedly would seem to be the right approach when one considers the great difference in character between the natural and the social sciences. It is therefore a pity that the author should have spoiled what seemed the right approach by a last chapter dealing with

the nature and prospects of the social sciences. Not only does it add nothing to the argument, but it contains statements which are not easy to reconcile with one another. For instance, in one passage, the author expresses the conviction "that social science is not only possible but even essentially the same as natural science", and that "social behaviour is determinate and that therefore a highly developed social science is possible"—a statement characteristic of the scientistic approach. But in another passage of the same chapter he speaks about the "positivistic bias of a great deal of nineteenth-century social theory", and of the lingering influence of this "misconceived and limited understanding of human behaviour" on social science. What is even more surprising is the fact that, in trying to establish a sameness between the natural and the social sciences, Dr. Barber has not even considered the powerful counter-arguments of such an authority as Professor Hayek. Indeed, amongst the 400 or so bibliographical references given by the author —which add considerably to the value of the book—there is not a single one to Professor Hayek's *Counter-Revolution of Science*, nearly all of which has been available since 1944.

The foregoing comments illustrate some of the difficulties that beset the sociology of science. From the sociologist's point of view, the main difficulty seems to be that, unlike most of the human activities which form the subject-matter of his investigations, science does not easily come within the grasp of one who has not been specifically trained in it. It is one of the most highly-specialized activities in a highly-specialized society, and its subtleties have a way of eluding the outsider.

Then, progress in the sociology of science does not seem to lie in a general survey of the whole field; it is more likely to be achieved by studying exhaustively a specific problem in the field. The contributions which have proved the most successful and the most useful are the more exhaustive studies on such subjects as the origins of modern science, the influence of scientific thought on a specific political doctrine, the sociology of scientific discovery or invention, the place of science in government, etc. Often the facts and data are to hand; the main task consists in placing them in a new system of relations with one another, in giving them a new framework. But, as Professor Butterfield once remarked, of all forms of mental activity, this is the most difficult to induce.

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